Cruise Report

R.V. Poseidon **Cruise No.: 291**

Dates, Ports: 26.6.2002 (Reykjavik) – 2.7.2002 (Akureyri) – 14.7.2002 (Reykjavik)

Research subject: Hydrothermal studies of Grimsey Field, volcanic studies of Kolbeinsey Ridge

Chief Scientist: Prof. Dr. Colin W. Devey, Univ. Bremen

Number of Scientists: 22 (2 legs)

Project: DFG De572/14-1 Fracture Zone

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1. Introduction

The 291st cruise of the research vessel Poseidon was aimed at increasing understanding of the volcanic transition zone between the island of Iceland and the Kolbeinsey spreading axis in the so-called “Tjörnes Fracture Zone” (e.g. Rögnvaldsson et al. 1998). The work concentrated on two main themes – the hydrothermal systems established along the submarine rift zones and the observation and sampling of the volcanic rocks. To this end we used gravity corers to penetrate into the sediments of hydrothermal fields and dredges and volcanic wax corers to sample the volcanics. A new sampling and observation tool for the Poseidon was the new Bremen ROV which was extensively tested and deployed during the cruise. The ROV provided high quality video data from the seafloor and was equipped with a claw for sampling and temperature sensors for work in the hydrothermal areas.

The work began during the first leg (Reykjavik – Akureyri) with intense sampling of the Grimsey Hydrothermal Field mainly with gravity corers. The main aim of this work as to recover pore water from the field to look at the chemical transport through the hydrothermal zone. Following a partial scientific crew change in Akureyri, the 2nd leg set out to follow and sample the volcanic rift zone through the Tjörnes transition. Due to the complicated tectonics and the shallow water depths this transition has never been clearly documented, the position of the spreading axis south of Kolbeinsey Island at ca. 67°09`N/18°40`W is poorly constrained until it reaches the north coast of Iceland at Axarfjördur (66°10`N/17°40`W). Seismic data (e.g. Rögnvaldsson et al. 1998) imply that the transition occurs on an oblique line between Axarfjördur and Kolbeinsey, this line has on previous surveys however not been found to be particularly volcanically active.

2. Bathymetric data from the Tjörnes area

2.1 Processing of echosound data (T. Kuhn)

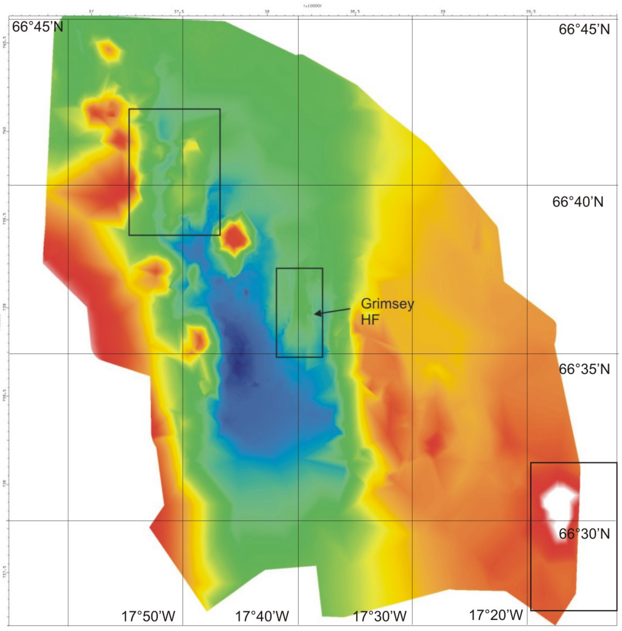


Fig. 2.1: General bathymetric map of the Grimsey Graben. The boxes mark areas which were mapped during POS-291. The N-S striking ridge along which the Grimsey hydrothermal field is situated was mapped with high resolution whereas the NW area as well as the Manareyar Ridge in the SE were mapped with lower resolution.

Due to lack of bathymetric maps in some parts of the working areas it was necessary to map the seafloor with the single beam echosounding system which is installed on R/V Poseidon (system: ELAC LAZ 4700 with 12 kHz). For detailed mapping ship's speed was 4 knots and the profiles were spaced about 100 m from each other. The recording system was set to record every 10 seconds resulting in data points ca. every 20 m along the profile. For mapping of larger areas, the ship's speed was increased to 6 knots resulting in data points roughly every 30 m along the profiles and the profiles were separated about 1.85 km from each other.

Detailed mapping has been carried out along the North-South ridge on which the Grimsey hydrothermal field is situated as well as between 67°02'N and 66°54'N along the Kolbeinsey Ridge. At a larger scale the southernmost tip of the Kolbeinsey Ridge, the NW area of the Grimsey Graben and the northern tip of the Manareyar Ridge have been mapped as outlined above (Fig. 2.1 & 2.2).

Data recording from the echosound system was done with the software PC-Log (vers. 5.4) installed onboard R/V Poseidon. The analysis of the bathymetric data and the creation of bathymetric maps was carried out with the software package gOcad® licensed to TU Bergakademie Freiberg. As a first step, the data were transformed from geographical data (Latitude, Longitude, water depth) into UTM data (Northing, Easting and water depth) using the software PanTool. The data was then loaded into gOcad® as a set of xyz-points. The creation of a bathymetric map from such a set of points was realized using the triangulation algorithm under the prerequisite of the Delauney criterion (Mallet, 2002). Fitting of the surface to the points has been optimized by iteratively running the discrete smooth interpolater, setting the points as constraints and optimizing the direction along which the

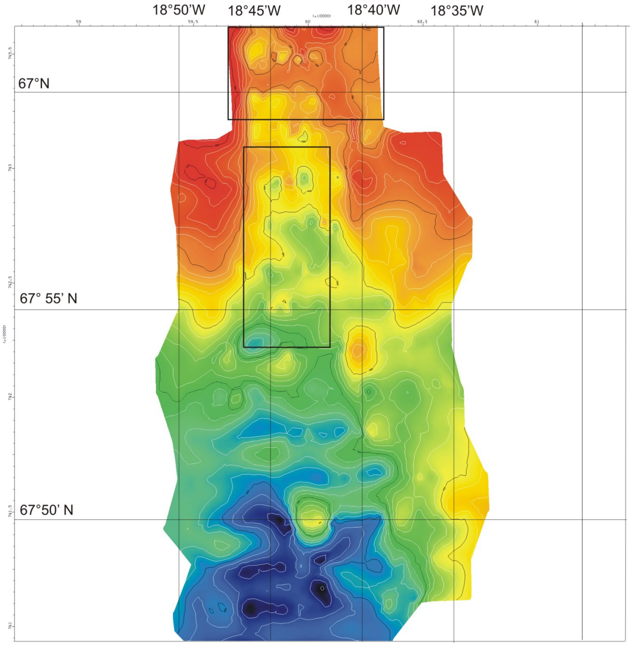


Fig. 2.2: General bathymetric map of the southernmost tip of the Kolbeinsey Ridge. The whole area was mapped during POS-291. The boxes mark regions mapped with high resolution as outlined in the text.

surface has to be moved to fit the data points (Fig. 2.3). The accuracy of the fit can be checked by calculating the misfits between the data points and the created surface. The computed errors are given in Tab. 2.1.

Table 2.1: Error parameters of the computed surfaces and the data points

Area[1]	*Mean*[2]	*Min.*[3]	*Max.*[4]	*Std.-Dev.*	*N*
Survey mapping southern Kolbeinsey Ridge	+ 0.13	- 46.3	+ 39.0	6.19	8130
Detail mapping of central area on KR	- 0.108	- 45.1	+ 47.9	7.86	3461
Detail mapping of northern area on KR	- 0,003	- 49.2	+ 35.4	4.69	12935
Detail mapping of Grimsey HF	- 0.0008	- 25.7	+ 19.8	3.36	37484
Mapping of NW area of Grimsey Graben	+ 0.082	-265	+112	7.57	12661
Mapping of Manareyar Ridge	- 0,012	-40.7	+ 26.8	3.83	8356

1: For location of areas look at Figs. 2.1 & 2.2
2: Mean deviation of surface from data points
3: Maximal distance of a data point below surface
4: Maximal distance of a data point above surface
All values are in meters and are related to depth (z) values.

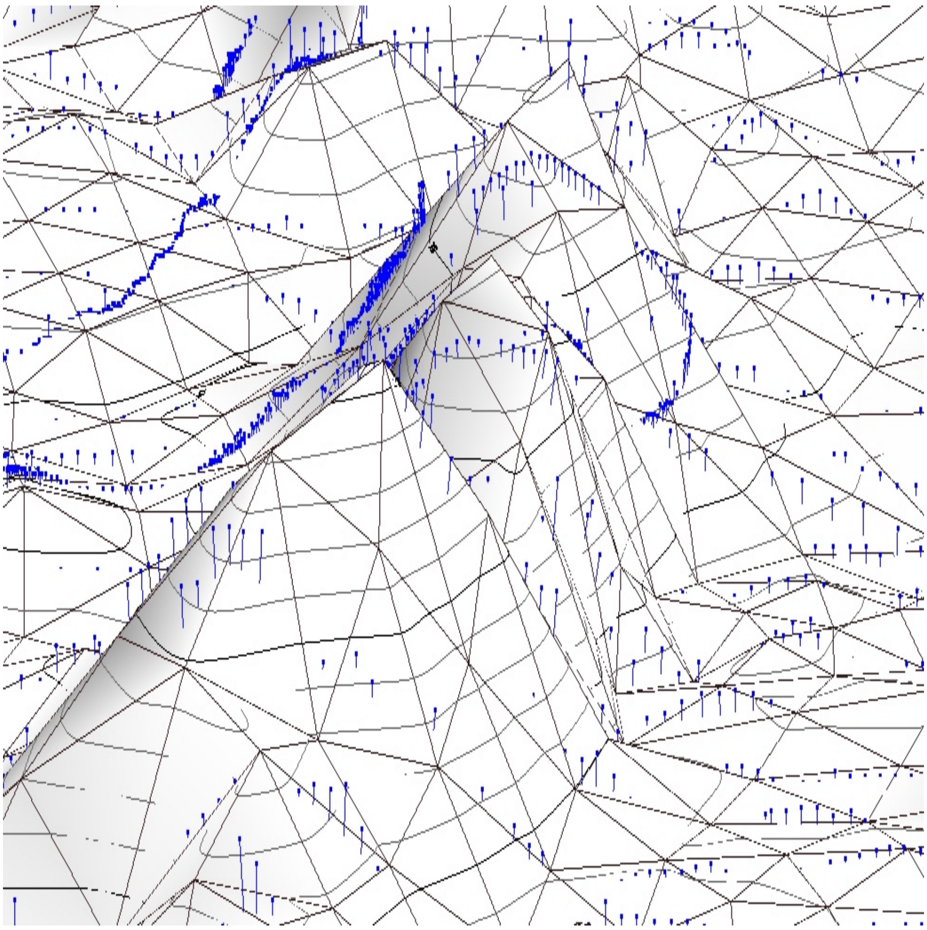


Fig. 3.3: Example of a set of data points and the computed surface. Blue lines from data points are „shooting directions“. The surface is triangulated, contour lines are also shown. Length of blue lines near the top of the hill in the foreground is about 15 m representing the misfits of data points and surface. The picture is three times vertically exagerated.

2.2 Bathymetry in the vicinity of the Grimsey hydrothermal field (T. Kuhn)

The Grimsey hydrothermal field (GHF) is situated along the eastern wall of a N-S trending ridge which itself lies on the eastern boundary of the Grimsey Graben (Fig. 2.1 & 2.4).

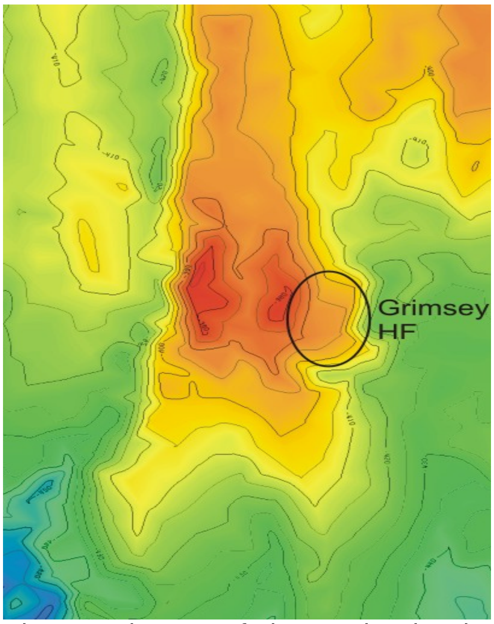


Fig. 2.4: Close-up of Fig. 2.1 showing the N-S striking ridge with the Grimsey hydrothermal field on its eastern slope. Note the distinct plateau which marks the GHF.

At the position of the GHF the ridge is about 1 km wide, it thins out to the north where it is only about 500 m wide. The ridge bifurcates at its southern tip before it disappears below the Grimsey Graben. Seismic records suggest that the ridge does not continue beneath the graben fill.

The western ridge margin steeply slopes towards the basin. At some parts it is even characterized by vertical walls some meters high, as a ROV video survey (see Chapter 5) has shown. In contrast, the eastern slope gently drops towards the basin. The Grimsey hydrothermal field is situated on a distinct plateau at the eastern slope. West of the plateau two small mounds mark the highest points of the N-S ridge.

A distinct offset characterizes the ridge at 66°36.7'N / 17°40.5'W (Fig. 2.5). South of this position the ridge strike slightly changes to NNE-SSW. The offset is located where a large fault striking N 43°W and probably representing the Grimsey fault crosses the ridge (Kuhn and Riedel, unpublished data). This fault also cuts through the ridge at the location of the GHF the position of which may therefore be structurally controlled.

The plateau on which the GHF is situated measures about 600 m N-S and 200 m E-W in 400 to 390 m water depth. ROV dives carried out during the cruise showed that the northern part of the plateau is made up of a mound-like structure about 10 m high topped by 4 active anhydrite chimneys. Its southern part is flat characterized by small depressions and single, small chimneys. Solitary chimneys also appear to the northeast of the plateau (Hannington et al., 2001).

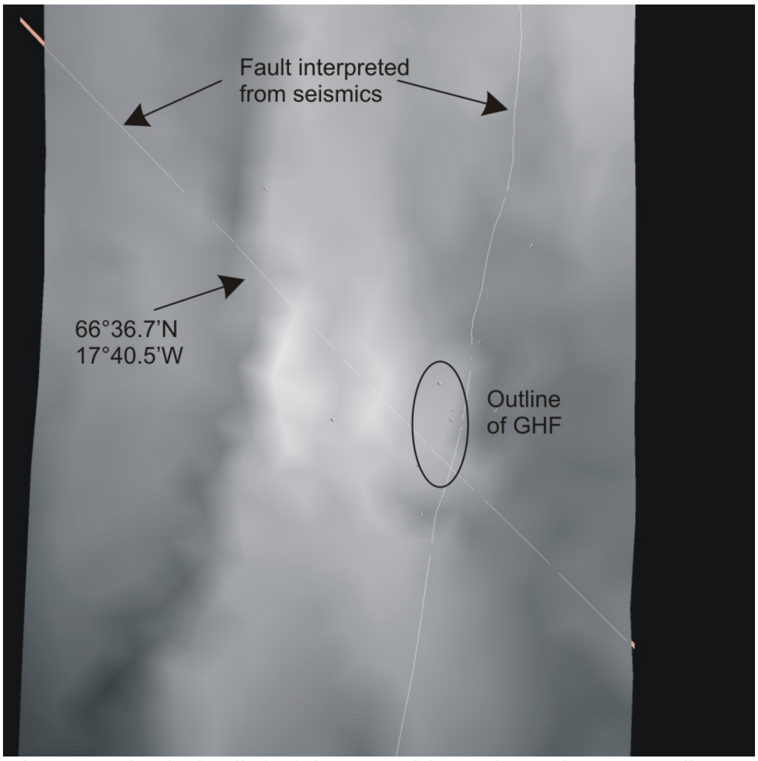


Fig. 2.5: Shaded relief of the N-S ridge. The Grimsey HF lies at the crossing point of two hypothetical faults. The western boundary of the ridge is marked by a distinct ridge which offsets at 66°36.7' N and 17°40.5'W. However, hydrothermal activity or precipitates were not detected during a ROV dive in this area. Long axis of the picture is about 5 km, north is up.

3. Sediment sampling in the Grimsey Hydrothermal Field

3.1 Sediment sampling during POS-291 (T. Kuhn)

Sediment sampling was conducted in the Grimsey hydrothermal field using gravity cores. A network of 14 cores were deployed both in the central area and the surroundings of the hydrothermal field. The scientific objectives were to reach deeper sediment depths compared to previous sampling and to determine the areal extent of the hydrothermal influence in the surroundings of the high-temperature hydrothermal field itself. The first objective was approached by 6 – 9 m cores (compared to 3 m cores during POS-253), the second one by measuring the sediment temperature at the core catcher on deck and by taking pore fluids.

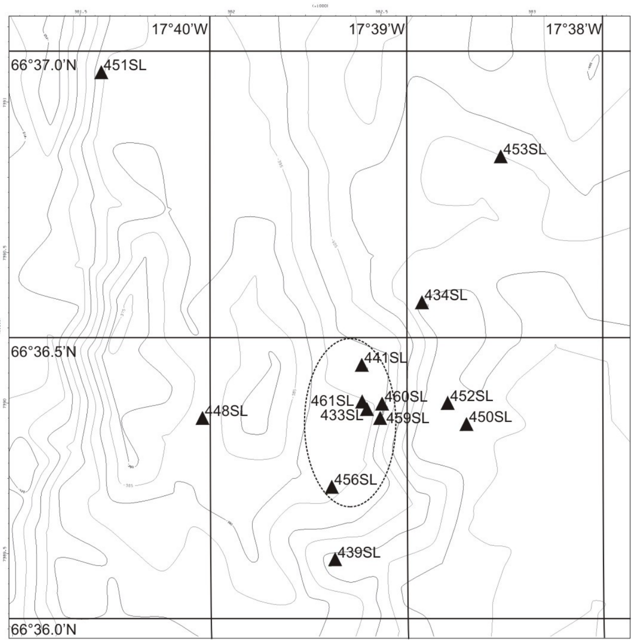


Fig. 3.1: Location of gravity cores taken during POS-291. The plateau along which the GHF is situated is also marked.

Sediments with hydrothermal alteration and hydrothermal precipitates such as disseminated sulfides, anhydrite and/or talc-like phases were only found in cores taken in the central part of the field (433SL, 441SL and 459SL, Fig. 3.1). These cores also show the highest temperatures at the core catcher: 101°C, 96°C, and 94.5°C resp. (Fig. 3.2, Table 3.1). The core 461SL, also taken from the central par,t shows a temperature of 71.5°C. Therefore, this core should also contain hydrothermal precipitates but it was not opened onboard due to lack of time. Another core sampled at the southern part of the hydrothermal field (456SL) contained some anhydrites in the core catcher with 36.9°C. The rest of the sediment was washed out probably during the rise of the core through the water column. All the other cores taken from the periphery of the field or the wider surroundings reach temperatures between 7.7°C and 27.1°C. Core 453SL taken from about 1200 m to the NNE of the central field still reaches 18.5°C which is far above background (about 4°C) and core 448SL taken about 600 m to the west still reaches 7.7°C (Fig. 3.2). Therefore, the Grimsey hydrothermal field is not limited to the vent field on the east slope of the N-S ridge but there is a much larger halo of diffuse fluid upflow. This halo may be elongate in its shape since the hydrothermal influence seems to be

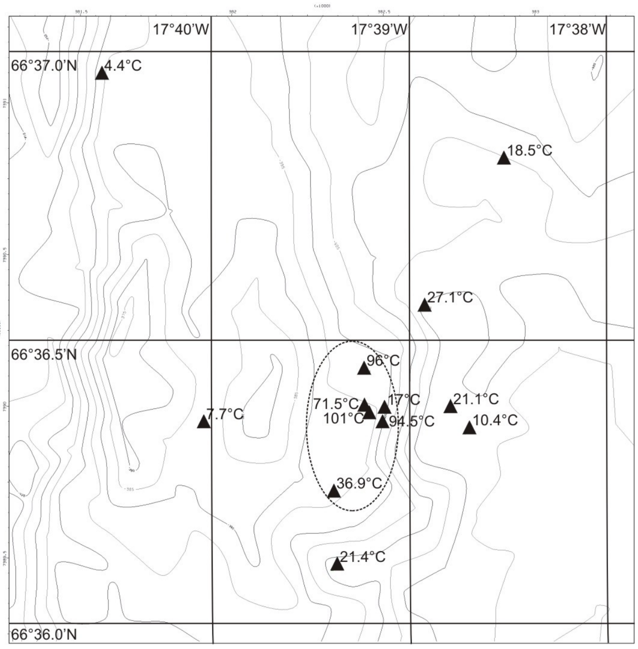


Fig. 3.2: Sediment temperatures measured in the core catcher on deck immediatley after recovering of the core. For depth of the core catcher see Tab. 3.1. Elevated temperatures resulting from upwelling hydrothermal fluids are not restricted to the GHF and may probably form a dome-like structure. Background temperatures are about 4°C found in core 451SL.

wider in N-S direction compared to the E-W direction. The core 451SL sampled about 2000 m to the NW of the hydrothermal field, however, showed background temperature at the core catcher.

Core descripitons can be found in the core logs (Fig. 3.3). Most sediments consist of hemipelagic clay derived from erosion of volcanic material on Iceland. The most notable features were found in sediments from the central hydrothermal field. These cores mainly consist of hemipelagic clay which is in some sections completely altered or baked due to hydrothermal overprint. For instance, clasts of hemipelagic baked clay occur in core **433SL** in a matrix of blueish altered sediments between 120 and 145 cm bsf. In this section the sediments have a breccia-like appearance which is similar to sediments which have undergone hydrofracturing due to high fluid pressure. Between 145 and 200 cm bsf fine-grained disseminated sulfides appear pervasively in the sediments. They mainly consist of pyrite. Below 280 cm bsf the sediments become dryer and contain a lot of small cracks. These cracks contain a higher amount of sulfides compared to their surroundings and may have acted as fluid pathways. The cracks could have developed after the sediments have been baked by hot hydrothermal fluids which might have moved horizontally below this layer. Beneath 360 cm bsf down to the core catcher at 485 cm bsf layers with a lot of black clasts with sharp edges ranging from about 1x1 cm down to sand-size occur together with 2-3 x 2-3 mm patches of fine-grained whitish material (anhydrite, talc-like phases?). The black clasts could have been volcanic particles completely hydrothermally altered to clay. Fine-grained sulfides also appear all over this section. Between 410 and 450 cm bsf olive-green to reddish clay-sized material occurs. This part may represent fluid channels where hot hydrothermal fluids react with pore water resulting in the formation of kerolite-stevensite (cf. Mau, 2001).

In core **441SL,** which is only 234 cm long, blueish altered clay surrounded by a bleached zone occur channelwise between 90 and 180 cm bsf. In the upper part of this zone a mixture of altered, bleached, and unaltered clay is mixed with sand-sized material probably representing ash. The lowermost 20 cm of this core are characterized by gatherings of black clasts which might be hydrothermally altered volcanic material as in 433SL. However, these clasts are different from the one in 433SL in that they do not have their sharp edges.

Core **459SL** contains reddish fragments between 65 and 165 cm bsf which could be oxidized sulfide fragments. This core also includes some hydrothermally altered ash layers that could have acted as fluid channels.

The sediment cores from the central hydrothermal field suggest a mainly horizontal hydrothermal fluid flow which dries out the sediments below and above until cracks start to form as a result of shrinking. Hydrothermal fluids may then be able to move upwards along these cracks.

Coarse-grained anhydrite detritus probably derived from destabilized anhydrite chimneys completely makes up core **456SL**. This core was taken from the southern part of the field. Another core sampled from this area during cruise POS-253 consisted of kerolite-stevensite which was interpreted to be the residue from otherwise completely dissolved anhydrite chimneys (Scholten et al., 2000). A ROV dive during this cruise (station 509) revealed that at least the part of the southern field surveyed consists of a flat plain with small depressions in which chimney detritus gathers. Sediment temperatures measured in core catchers from cores of the southern field didn't reach such high values as found in the northern part either during this cruise or during POS-253 (Fig. 3.2 and (Scholten et al., 2000). Therefore, the southern part of the field might already represent the periphery of the Grimsey hydrothermal field. From the distribution of sediment temperatures measured in core catchers it seems as if there is a dome-shaped upwelling of hydrothermal fluids along the NNE-SSW oriented fault interpreted in Fig. 2.5.

Table 3.1: Sediment Stations of POS-291.

Station Number	LAT	LONG	Depth	Remarks
432 SL9	66°36,40'N	17°39,34'W	392 m	core barrel bent, 50 cm core recovery temperature at core catcher: backround temperature
433 SL6	66°36,36'N	17°39,24'W	396 m	temperature at core catcher: 101 °C
434 SL6	66°36,56'N	17°39,01'W	417 m	temperature at core catcher: 27,1 °C
439 SL12	66°36,09'N	17°39,36'W	406 m	temperature at core catcher: 21,4 °C
441 SL6	66°36,44'N	17°39,27'W	391 m	temperature at core catcher: 96 °C
448 SL6	66°36,33'N	17°39,98'W	385 m	temperature at core catcher: 7,7 °C
450 SL12	66°36,34'N	17°38,79'W	422 m	sediment droped out temperature at core catcher: 10,4 °C
451 SL6	66°36,94'N	17°40,51'W	395 m	temperature at core catcher: 4,4 °C
452 SL6	66°36,38'N	17°38,88'W	417 m	temperature at core catcher: 21,1 °C
453 SL6	66°36,82'N	17°38,69'W	411 m	temperature at core catcher: 18,5 °C

456 SL6	66°36,21'N	17°39,38'W	391 m	anhydrite washed out temperature at core catcher: 36,9 °C
457 SL6	66°34,49'N	17°39,67'W	388 m	washed out
459 SL6	66°36,35'N	17°39,18'W	396 m	temperature at core catcher: 94,5 °C
460 SL6	66°36,37'N	17°39,18'W	397 m	baked mud temperature at core catcher: 17 °C
461 SL6	66°36,38'N	17°39,26'W	397 m	temperature at core catcher: 71,5 °C

3.2 Microbiological studies *(Viggó Thór Marteinsson, Cédric F.V. Hobel)*

3.2.1 Aims of the research

Our main interest is the bio-diversity of both aerobic and anaeobic cultivated and non-cultivated microorganism in samples retrieved from the hydrothermal vent field at Grímsey area. For this purpose we aimed to perform sampling of cores, retrieve chimney samples taken by the ROV and to deploy bacterial traps on diffusion water with the ROV.

3.2.2 Work performed on board

Cells were extracted from the core samples with sterile, artificial sea water (2% NaCl), separated from mud and sand by a 2-step centrifugation and stored below -20°C (see Tables 3.2 & 3.3). Core samples were also collected for cultivation and stored under anaerobic conditions at 4°C (Marteinsson et al., 2001).
Pelagic mud was accidentally retrieved by dredging a glass field (station #493). Cell were treated similarly to those from the core samples in order to perform both aerobic and anaerobic cultivation later on in the laboratory.
Only one piece of chimney was retrieved (ROV Dive #7, sample #514). The sample was cut in two parts. One piece (514_1) was stored in sterile, artificial sea water (2% NaCl) and sterile 25% glycerol for aerobic cultivation. The sample was frozen directly at –20°C. The second part of the sample (514_2) was kept under anaerobic conditions at 4°C.
No bacterial traps were used due to technical problems encountered during their deployment from the ROV.

3.2.3 Work planned in the laboratory

We plan to do some enrichments for anaerobic and aerobic thermophilic microorganisms from the samples and to isolate some strains from the enrichments. Partial sequence of the 16S rRNA genes will be analysed in some isolated strains and new species will be described.
DNA will be extracted from obtained biomass (extracted cells from the core samples). The phylogenetic diversity of the microbial community developed in the samples will be analysed with PCR amplification and partial sequence of the 16S rRNA gene will be analysed (Marteinsson et al., 2001).

Table 3.2: Core samples taken for microbiological studies (samples stored at Prokaria Inc.)

Station no.	Section	Sample description	-20°C	-O_2 4°C
SL 432		Core sample (H2S)	+	+
SL 434	Section 1	80 cm from the top	+	+
	Section 2	80 cm from the top	+	+
	Section 3	80 cm from the top	+	+
	Section 4	80 cm from the top	+	+
	Section 5	Mixed (27°C on deck)	+	+
SL 439	Section 1+2	Mixed 850-1050 cm (21.4°C on deck)	+	+
	Black layer	Ash at 900-915 cm	+	+
	Section 3	75 cm from the top	+	+
	Section 10	80 cm from the top (seafloor)	+	+
SL 441	Section 1	(15) cm from the top (seafloor)	+	+
	Section 2	(40) cm from the top (96°C on deck)	+	+
SL 448	Section 5	80 cm from the top (38-138 cm)	+	+

	Section 1	70 cm from the top (438-538cm) (7°C on deck)	+	+
SL 452	Section 1	60 cm from the top (400-500 cm)	+	
	Section 2	60 cm from the top (300-400 cm)	+	
	Section 3	60 cm from the top (200-300 cm)	+	
	Section 4	60 cm from the top (100-200 cm)	+	
	Section 5	60 cm from the top (0-100 cm) (21°C on deck)	+	+
SL 459	Section 1	16 cm from the top (165-265) (94.5°C on deck)	+	+
	Section 1	72 cm from the top (165-65)	+	+
	Section 2	25 cm from the top (165-65)	+	+
	Section 2	55 cm from the top (165-65)	+	+
	Section 2	85 cm from the top (165-65)	+	+
	Section 3	35 cm from the top (65-0)	+	+
SL 461	Section 1	Hole core 100 cm (71.5 °C on deck)		+
	Section 2	Hole core 100 cm		+
	Section 3	Hole core 45 cm		+

Table 3.3: Biomass samples taken (sediments, chimney)

Station No.	Sample Description	-20°C	-O_2 4°C
493DS	Sediments by dredging new glass lava (cold sediments)	+	+
ROV514	Anhydrite chimney	+	+

3.3 Pore water sampling *(J. Scholten, D. Garbe-Schönberg)*

The Grimsey hydrothermal field is a shallow water, sediment-hosted hydrothermal system. The vent field consists of up to 20 mounds with anhydrite chimneys. Boiling fluids with temperatures of about 250 °C emanate from these chimneys. The composition of vent fluids sampled during previous cruises to Grimsey suggests that sub-seafloor boiling has a significant imprint on the hydrothermal fluids. The presence of a boiling aquifer beneath the deposit was identified by the high temperatures of sediments recovered during Poseidon cruise 253 in 1999. These sediments are composed of baked mud. Veins in the sediments indicate hydrothermal sediment alteration.

One objective of Poseidon cruise 291 was to penetrate the subseafloor hydrothermal aquifer by means of long sediment cores and to sample pore water fluids from these sediments. By comparing the chemical composition of sediment pore waters with the vent fluids the influence of sub-seafloor boiling on the metal-carrying capacity of the hydrothermal fluids should be investigated. A further objective was the identification of the origin and possible interactions of the fluids with sediments and volcanic rocks.

During Poseidon cruise 291 six cores were chosen for sampling of pore waters. Four cores (434SL, 439 SL, 448 SL, 452 SL) were situated at the rim of the Grimsey field and two cores (441 SL, 459 SL) in the centre of the field. Sediment cores were opened immediately after retrieval and transferred to a glove bag filled with argon. Pore water was extracted using an all-teflon pore water press with 0,2µm membrane filters. Pore water for analyses of trace metals were acidified, a separate sample for the determination of nutrients was deep-frozen. Details on pore water samples are given in Tab. 3.4. Analyses of the samples will be performed in the home labs.

Table 3.4 List of pore water samples obtained during POS 291.

434 SL	439 SL	441 SL	448 SL	452 SL	459 SL
(cm)	(cm)	(cm)	(cm)	(cm)	(cm)
8-13	45-50	55-60	80-85	45-50	78-83
43-48	200	85-90	180-185	145-150	106-111
77-82	300	110-115	280-285	245-250	135-141
117-122	400	155-160	380-385	345-350	185-191

147-152	500	185-190	480-485	445-450	223-228
185-190	600	210-215			
205-210	700				
225-230	780-785				
245-250	825-830				
265-270	880-885				
285-290	925-930				
305-310	980-985				
325-330	1025-1030				
345-350					
365-370					
385-390					
405-410					
425-430					
430-445					
465-470					

4. Rock sampling in the Tjörnes Transition

Following the work at Grimsey Hydrothermal Field during the first leg, the main rock sampling programme began to the south of Kolbeinsey Island at around 67°03´N and proceeded to trace the spreading axis southwards toward the Iceland anomaly. A description of all samples recovered and the location at which they were taken is given in Chapter 6. The most northerly dredges were performed in the area immediately south of the Kolbeinsey Hydrothermal Field (see Figure 4.1, star marks the hydrothermal field). The two dredges taken on the western flank of the active rift zone marked by the hydrothermal field yielded old material lacking glass crusts. Dredges on a high in the rift valley in contrast yielded fresher samples with glass crusts (although still with a coating of benthos). Immediately to the south of the area shown in Figure 4.1, a series of closely spaced profiles yielded depth data which, using a digital surface fitting software described in Chapter 2, were used to produce a map of the seafloor. This map is shown in Figure 4.2 (a view from the south). The area is characterised by a linear rampart-like slope in the far west (on left hand side of Figure 4.2). The eastern limit of the area is also marked by a broad, N-S trending massif, the topogaphy of this massive is however less dramatic than in the west. The valley between the two N-S-trending massifs contains several discontinuous ridges. They appear to fall on two N-S-trending alignments, the more westerly of these bends progressively westwards as it is followed south. The more easterly ridge is characterised by very shallow depths at its most northerly mapped extent, these depths become more subdued towards the south, showing a major deepening at approximately the same latitude as the eastern rampart also increases in depth.

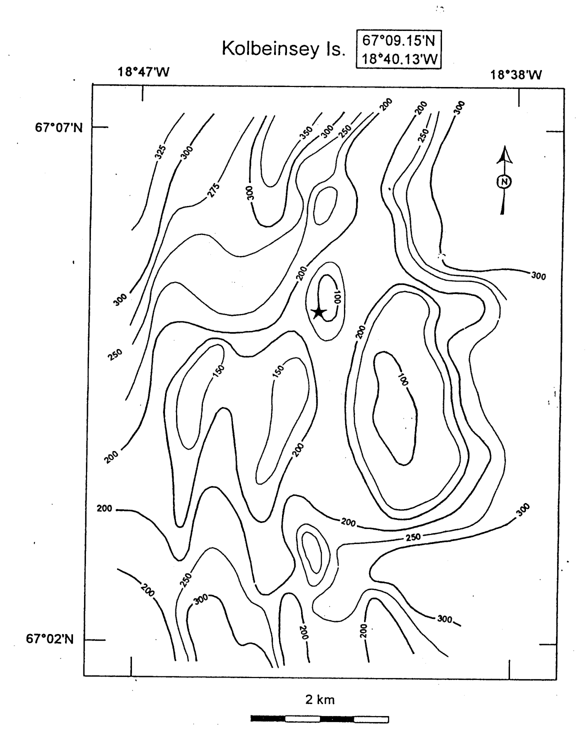


Figure 4.1: Bathymetry of the Kolbeinsey Ridge near the Kolbeinsey Hydrothermal Field (star)

Sampling and observation tracks in the area mapped lead to the following conclusions:

- ?? The area between the ramparts represents the neovolcanic zone. Dredges taken in the area immediately to the north (see Figure 4.1) yielded samples from the flanking highs which are, based on sample freshness, older than those from the valley
- ?? Of the within-rift ridges, the more easterly appears to be younger, yielding samples with very fresh glass crusts and a minimal benthos coating.
- ?? The peak areas of the within-ridge highs are the youngest volcanic zones (see, for example, observations of ROV dive #3, station 464ROV, Chapter 5). In the saddles between the peaks the seafloor is sediment-covered.

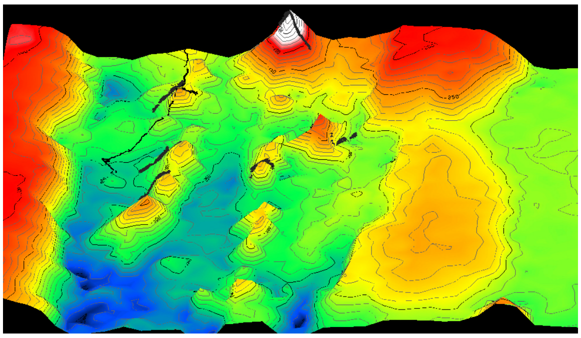


Figure 4.2: Bathymetry of the most northerly area studies (location see Figure 2.2, upper box). For discussion see text. Dark lines show locations of ROV dives.

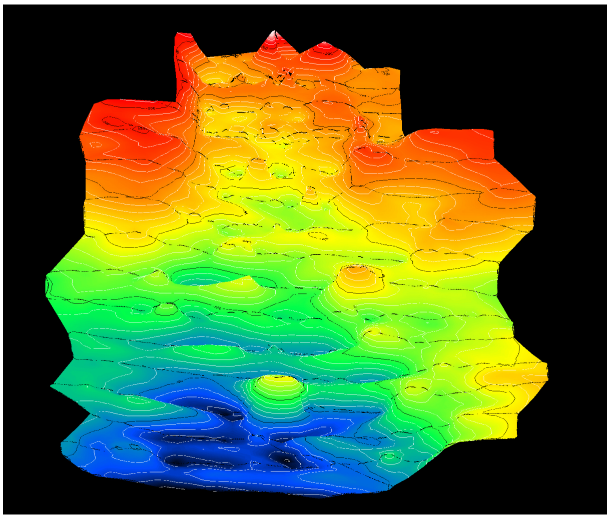


Figure 4.3: The southern end of the South Kolbeinsey Ridge which gradually deepens and become less well defined towards the south (bottom of Figure). For location of Figure on large scale see Figure 2.2, lower box.

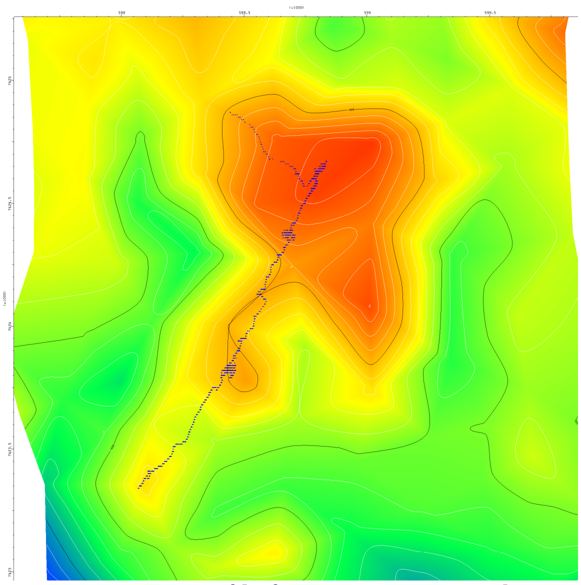


Figure 4.4: ROV profile for station 497ROV, the starting point was at the lower left, the dive finished on the top of the seamount at the northwest side of the summit plateau.

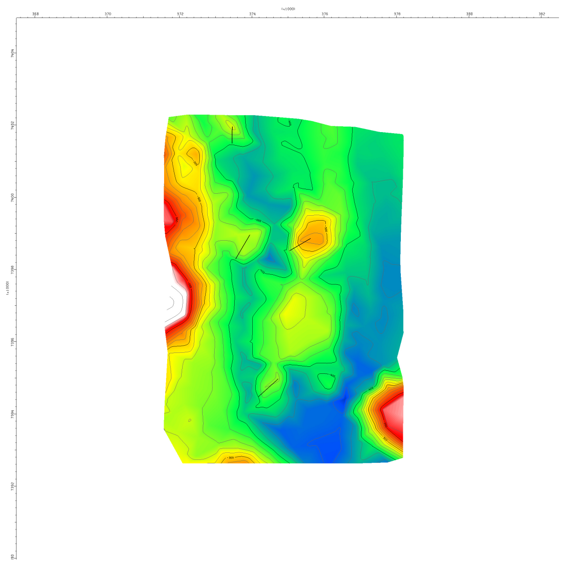


Figure 4.5 Dredge stations to the north ans east of Grimsey Island. Location of map shown on Figure 2.1, uppermost box.

The more active of the within-rift highs runs very nearly N-S along longitude 18°43´W. Using this information, E-W profiles were then run at 1´ N-S separation in order to follow this rift structure southwards. The results are shown as a map produced from the widely-spaced sections in Figure 4.3 (3d view from the south, thicker lines running left-to-right mark the profile lines on which the figure is based, location of Figure shown in Figure 2.2). The narrower area at the top of Figure 4.3 is the area represented in Figure 4.2. We see that the flanking ramparts which so characterised the area shown in Figure 4.2 become less prominent towards the south. The rift valley also becomes progressively deeper and shows a much more subdued within-rift morphology. The dredge attempts at the southern end of this feature (including the large peak at approximately 66°49´N seen in the lower centre of Figure 4.3 north of the deep blue-coloured trough) showed the surface to yield either no or only old, weathered rocks suggesting that the rift becomes extinct to the south. The most southerly latitude at which glassy samples where recovered is 66°54´N. Using this information and details from the mapping presented above, station 497ROV) investigated one of the southern-most volcanic structures in the rift valley. The ROV profile (Figure 4.4) showed the large within-rift high to be relatively old, covered with benthos and with no recognisable volcanic surface features. The ridge adjoining the high to the SW on the other hand is composed of almost unsedimented pillows and tubes looking much younger than the main edifice. This suggests that recent volcanism in this part of the spreading axis has occurred along fissures which are not necessarily orientated parallel to the plate motion vector – the young volcanic ridge seen during ROV dive 497 trends NE-SW, almost at 45° to the direction of plate motion. In order to better understand the development of this ridge, several wax-corers stations were performed to collected closely spaced, well localised samples from the ridge.

Having followed the active volcanism as far south as possible on the Southern Kolbeinsey Ridge at 66°54´N, the search for volcanic connection to the neovolcanic zone of Iceland continued to the East. Dredging of several edifices north and west of Grimsey between 66°34´N – 66°40´N and 17°45´W-18°00´W yielded no fresh rocks. Nevertheless more extensive mapping was then carried out in this area (Figure 4.5) and dredging of targets identified during this work yielded some fresher material (from the larger edifice top centre of Figure 4.5).

The closest approach made to the neovolcanic zone in Axarfjördur was on the Manareyjar Ridge (also known as Tjörnesgrunn). Here both the ridge itself and a prominent seamount to the west of the ridge tip (near 66°32´N/17°20´W) were mapped (see Figure 4.6) and extensively dredged. The seamount yielded glassy samples from its summit – the summit region of the ridge (in ca. 80m of water) yielded blocks of indurated, volcaniclastic sediment.

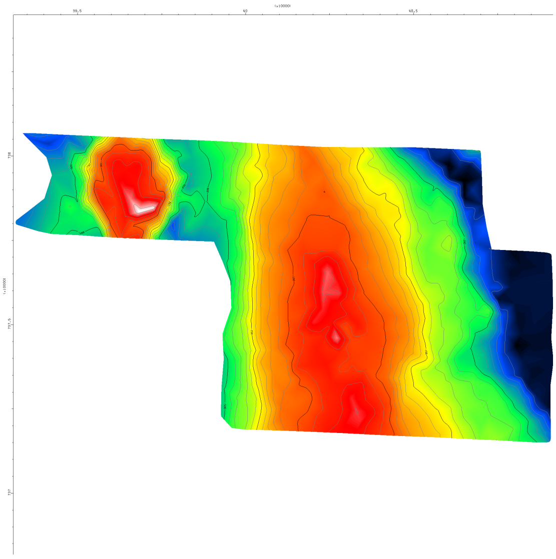


Figure 4.6: The Manareyir Ridge and adjacent seamount. For location see lower right-hand box in Figure 2.1

5. ROV deployment in the Tjörnes Transition

5.1 Dive descriptions

The POS291 cruise was the first operational cruise for the Bremen Cherokee ROV. The first two dives were test dives to check equipment and functionality of the ROV, the dives numbers 3 (Station POS464) and above (Stations POS489 = Dive 4; POS496 = Dive 5; POS 509 = Dive 6; POS514 = Dive 7; POS 518 = Dive 8) were working deployments. The following logs give information on the working deployments and are divided into two sections, firstly those with igneous targets on the southernmost end of the South Kolbeinsey Ridge (north and west of Grimsey Island) and those on the Grimsey Hydrothermal Field (east of Grimsey Island).

5.1.1 South Kolbeinsey Ridge Dives (K. Lackschewitz)

***Dive 3*: POS 464 (ROV Cherokee)** ***Area*: southern Kolbeinsey Ridge**

Time	Depth	Heading	GPS Ship	Comments
12:02	347	270	67°00.87 N 18°45.52 W	First sight of bottom, yellowish brown sediment (100%). Many Shrimps above the seafloor.
12:15	345	285	67°00.91 N 18°45.46 W	Landing on bottom, yellowish brown sediment covering 100% of the seafloor.
12:17	344	0		ROV is going northward
12:39	336	265	67°01.03 N 18°45.12 W	Yellowish brown sediment coverage (100%), ROV is diving upslope
13:09	315	009	67°01.22N 18°44.86W	First occurrence of volcanic blocks in variable dm- to m-size, outer surface of the blocks is completely covered by sponges and algae
13:27	283	355	67°01.35 N 18°44.64 W	Volcanic block mound, all blocks covered with algae and sponges
13:29	265	025	67°01.37 N 18°44.63 W	Top of the mound, mainly massive material, some showing pillow form
13:30	264	040		Off bottom
13:33	264	014	67°01.40 N 18°44.59 W	Volcanic block mound, all blocks fully covered by sponges and algae, in some place m-sized pillows
13:41	269	082	67°01.43 N 18°44.62 W	Off bottom
13:49	271	343	67°01.43 N 18°44.62 W	Volcanic blocks covered by overgrown by sponges and algae
13:51	285	319		Off bottom
14:11	283	347	67°01.43 N 18°44.46 W	Volcanic blocks, some showing pillow forms
14:19	284	031	67°01.44 N 18°44.49 W	Some yellowish brown sediment between the volcanic debris
14:20	286	028	67°01.44 N 18°44.50 W	Off bottom
14:22	287	267	67°01.44 N 18°44.51 W	Yellowish brown sediment coverage with some scattered blocks
14:24	284	027	67°01.44 N 18°44.51 W	Volcanic block mound with sediment in interstices
14:32	283	084	67°01.44 N 18°44.53 W	Off bottom
15:00	295	313	67°01.48 N 18°44.59 W	Volcanic block mound, all blocks are covered with sponges and algae, some blocks show pillow form
15:06	289	013	67°01.52 N 16°44.55 W	Sediment patches between the volcanic debris.
15:10	309	358	67°01.54 N 18°44.56 W	Steep slope down to the NW, ROV is following the volcanic block mound eastwards to the top.
15:14	306	053	67°01.57 N 18°44.61 W	Off bottom

15:18	297	326	67°01.71 N 18°44.55 W	Yellowish brown sediment with some scattered blocks
15:31	294	226	67°01.67 N 18°44.52 W	Volcanic block mound, all blocks overgrown by sponges and algae
15:37	304	344	67°01.71 N 18°44.55 W	Off bottom
16:03	284	025	67°01.88 N 18°44.59 W	Yellowish brown sediment (100% coverage) with some dark patches.
16:21	284			End of dive

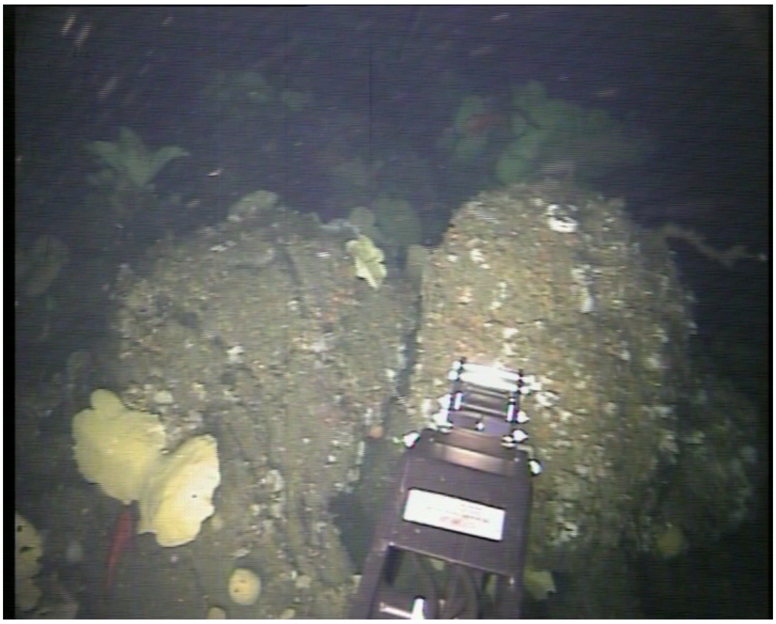


Figure 5.1: Typical view of algal coating on pillow heads, ROV dive 3 taken by frame capture from digital video

***Dive 4*: POS 489 (ROV Cherokee)** ***Area*: southern Kolbeinsey Ridge**

Time	Depth	Heading	GPS Ship	Comments
11:02	131	031	67°01.75 N 18°43.24 W	First sight of bottom, seafloor is covered with sponges and algae (100%).
11:04	135	040	67°01.74 N 18°43.28 W	Off bottom.
11:12	127	015	67°01.74 N 18°43.21 W	Seafloor is covered with sponges and algae (100%).
11:17	137	126	67°01.74 N 18°43.12 W	Deep slope to the southeast.
11:18	140	02	67°01.74 N 18°43.11 W	Deep slope to the northwest, volcanic talus on top of the ridge, rocks are overgrown by sponges and algae.
11:20	139	329	67°01.73 N 18°43.11 W	Landing on bottom for rock sampling. **Sample 1:** Rock fragment overgrown by sponges and algae.
11:31	133	060	67°01.75 N 18°44.12 W	Going northwards to find the end of the ridge top.
11:35	143	316	67°01.74 N 18°44.08 W	End of the ridge top, going hang-parallel, slope consists of volcanic talus covered by sponges and algae (100%).
11:48	151	301	67°01.74 N 18°44.07 W	Steep wall showing some uncoverd, altered surfaces of volcanic rocks, brown sediment in interstices.
11:53	162	337	67°01.73 N 18°44.06 W	Diving along the wall which is covered by fine sediment and black volcanic gravel.
12:01	172	312	67°01.74 N 18°43.01 W	Ridge top with dm-sized volcanic debris, rocks covered by sponges and algae.
12:05	175			Off bottom.
12:15	123	346	67°01.75 N	Slope with volcanic talus overgrown by sponges and algae.

			18°44.16 W	
12:18	129	100	67°01.76 N 18°43.24 W	Off bottom.
12:36	129	112	67°01.75 N 18°43.13 W	Landing on a volcanic talus field. **Sample 2**: Volcanic rock covered with sponges and algae.
12:50	125	173	67°01.78 N 18°43.21 W	Proceeding to dive hang-parallel.
12:55	137	095	67°01.77 N 18°43.25 W	Off bottom.
13:20	123	313	67°01.75 N 18°43.17 W	End of dive.

***Dive 5*: POS 496 (ROV Cherokee)** ***Area*: southern Kolbeinsey Ridge**

Time	Depth	Heading	GPS Ship	Comments
11:25	425	033	66°54.72 N 18°45.51 W	First sight of bottom, yellowish brown sediment (100%) with a few cm- to dm-sized rocks, some rocks are overgrown by sponges and algae.
11:32	425	302	66°54.74 N 18°45.47 W	Off bottom
12:00	434	129	66°54.80 N 18°45.31 W	Arrived on bottom, yellowish brown sediment with sme rocks, a few rocks are covered by sponges
12:02	435	105		Off bottom
12:15	430	290	66°54.87 N 18°45.18 W	Scattered volcanic rocks (dm- to m-size) on the sediment surface, most rocks are relatively fresh, some pillows covered by a few sponges and algae.
12:17	434	225	66°54.89 N 18°45.15 W	Lava tube close to a fragmented pillow.
12:19	432	276	66°54.89 N 18°45.15 W	Pillow pile overgrown with algae and a few sponges.
12:24	434	256	66°54.91 N 18°45.12 W	Large lava tube (ca. 1 m), tube surface is showing several cracks.
12:28	429	133	66°54.92 N 18°45.10 W	Off bottom.
12:44	404	070	66°54.97 N 18°45.01 W	Pillow pile with some lava tubes.
12:58	403	140	66°54.97 N 18°44.98 W	Stop on the ground in front of a lava pillow, several unsuccessful attempts to grab stones.
13:04	407	078	66°54.97 N 18°44.97 W	Brown sediment with some scattered pillows and lava tubes.
13:09	403	064	66°54.98 N 18°44.98 W	Stop on the ground in front of a pillow pile.
13:14	405	357	66°54.97 N 18°44.96 W	Open pillow.
13:27	406	072	66°54.96 N 18°44.98 W	Another pillow pile.
13:29	404	126	66°54.96 N 18°44.98 W	Steep slope to the south.
13:32	403	014	66°54.98 N 18°44.97 W	Large lava tube (ca. 1 m).
13:33	402	158	66°54.98 N 18°44.98 W	Large open pillow fragment.
13:36	406	092	66°54.97 N 18°44.99 W	End of pillow pile, off bottom.
13:56	399	030	66°55:01 N 18°44.95 W	Top of pillow pile, thin sediment cover, some sponges and bryzoens.
14:13	406	047	66°55.07 N 18°44.83 W	Large lava tube (ca. 1 m).
14:20	412	352	66°55.10 N 18°44.79 W	Lava worms and fresh pillows.
14:23	414	301	66°55.14 N 18°44.79 W	Off bottom.

14:31	412	045	66°55.17 N 18°44.75 W	A few pillows with large biomass and a thin sediment cover on top
14:33	410	043	66°55.17 N 18°44.75 W	Transition from pillow pile to sediment covered surface, a few rocks overgrown with sponges and algae.
14:38	413	065	66°55.20 N 18°44.71 W	Increasing amount of sediment covered rocks, a lot of sponges.
14:40	416	066	66°55.21 N 18°44.70 W	Several pillows, top of pillow pile.
14:42	418	062	66°55.21 N 18°44.69 W	Fresh pillow pile at the SE flank.
14:45	418	079	66°55.22 N 18°44.69 W	Off bottom
14:47	410	075	66°55.23 N 18°44.66 W	Lava worms covered with anemons.
14:54	384	336	66°55.26 N 18°44.63 W	Pillows covered with lot of biomass.
15:00	380	345	66°55.27 N 18°44.63 W	Off bottom
15:17	378	002	66°55.27 N 18°44.59 W	Sediment cover with some scattered rocks and lot of biomass.
15:37	367	078	66°55.32 N 18°44.55 W	Steep wall to the north, high amount of biomass along the upper wall.
15:45	358	002	66°55.35 N 18°44.50 W	A lot of platy rock fragments.
15:50	333	052	66°55.38 N 18°44.50 W	Mainly sediment with some rocks and lot of biomass.
16:07	331	206	66°55.40 N 18°44.44 W	End of dive.

Figure 5.2: Pillow tubes and heads with relatively little biological coating despite the soupy water.

5.1.2 Grimsey Hydrothermal Field dives (T. Kuhn)

Three ROV dives were carried out on the N-S ridge, one of them on the western slope and two of them on the eastern slope within the Grimsey hydrothermal field (Fig. 5.3). The objective of dive 509 was to find the southern extension of the GHF. Dive 514 was carried out to map in detail the single chimneys and the central hydrothermal mound of the GHF with both a video and a sonar survey. Furthermore it was planned to take samples for microbiological and geochemical analysis. Dive 518 on the western slope of the ridge was aimed at checking for hydrothermal activity and precipitates since this is the location of the ridge offset shown in Fig. 2.5.

The main results of the dives are given below. See dive logs for details.

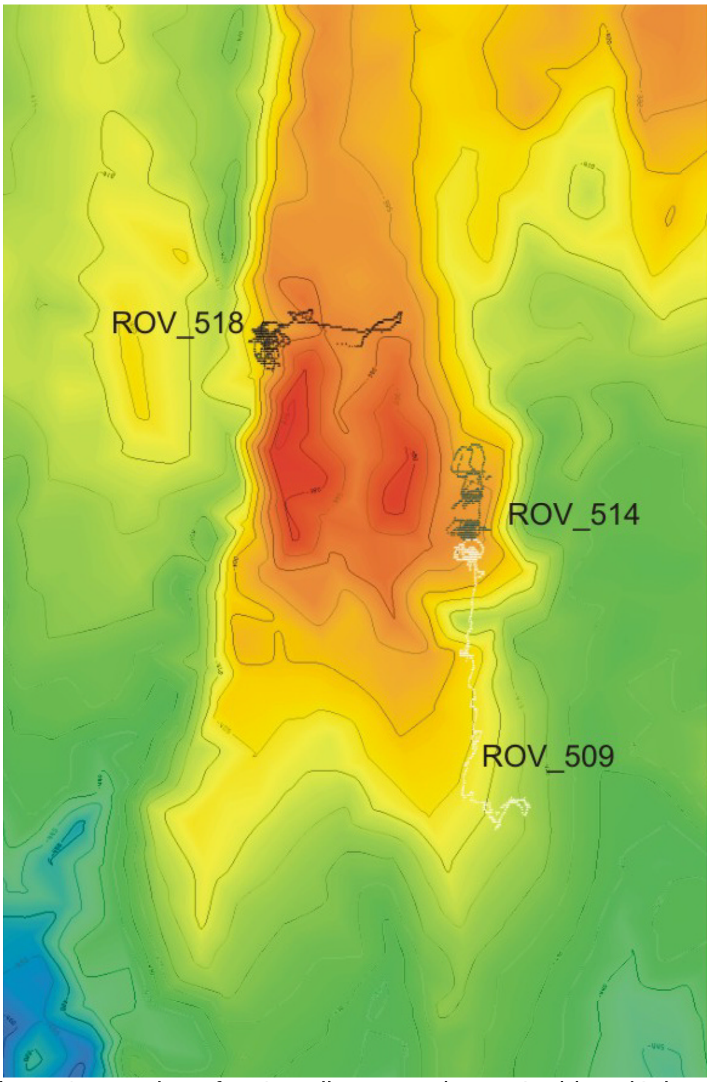


Fig. 5.3: Tracks of ROV dives on the N-S ridge (Grimsey Graben). For location of the ridge see Fig. 1.

Dive Nr. 6 (Station 509ROV)

Objective: To find out the southern extension of the central GHF. To carry out some sediment temperature measurements. To carry out sonar surveys.

One of the main results of dive 509 is that hydrothermal precipitates do not appear south of 66°36.25'N/17°39.26'W. In the area south of 66°36.20'N only hemipelagic sediments occur sometimes charactized by large ripples being N-S (± 45°) oriented, sometimes showing large trawling tracks from fishing nets, but mainly being structureless. Slight increase in surface sediment temperature of about 0.1°C was detected between 66°36.04'N and 66°36.20'N.

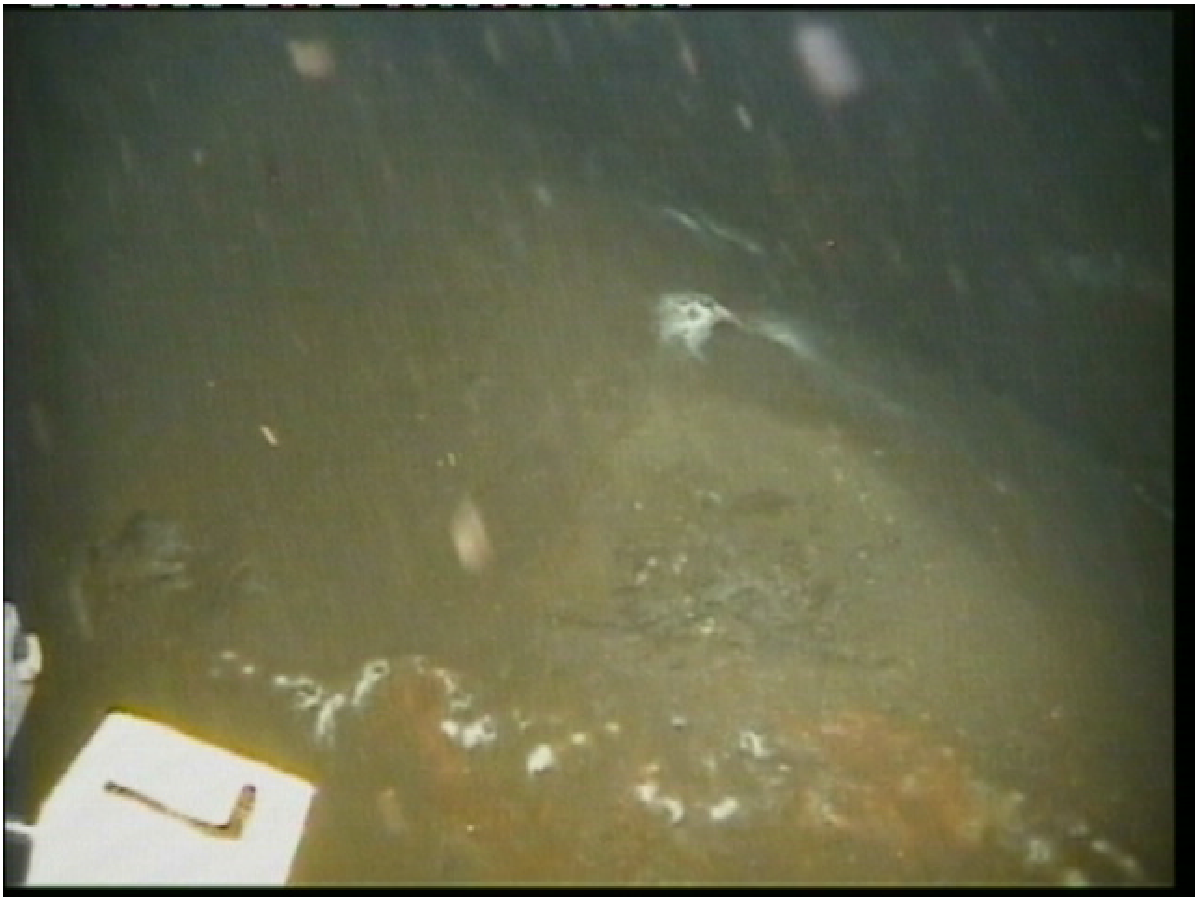


Fig. 5.4: Typical seafloor structure in the southern part of the Grimsey hydrothermal field. The top of a small ridge is characterized by a small depression (collapse structure?) surrounded by white patches (probably anhydrite) and stained sediments (probably Fe oxyhydroxides). Photograph taken during ROV dive 509. The depression is about 0.5 m across.

Hydrothermal precipitates north of 66°36.25‘N mainly consist of white patches (probably anhydrite) sitting on top of elongated mounds. These patches being more or less circular are surrounded by yellowish to reddish Fe oxyhdroxides (Fig. 5.4). A few small, inactive anhydrite chimneys were seen on the edge of such structures. Pockmarks with emanating gas bubbles are irregularly distributed over the elongated mounds.

Dive Log:

Date: July 09, 2002
Time: 11:25 – 19:15 UTC
Depth Range: 380 – 425 m
Location: southern Grimsey hydrothermal field

Time	Depth (m)	Heading	Position	Comments[1]
11:25				Begin of station
11:30	20			Tests in water
12:20	20			Begin lowering to seafloor
12:43	406			Bottom sight; ocean floor sediment covered, current ripples NW-SE
12:45	406			moving over waypoint 1 (66°35.72‘N / 17°39.05‘W)
13:00	409			structureless sediments, sometimes ripple marks but they could also be trawl tracks
13:12	402			T measurement in 0-50 cm depth: background
13:30	399			lots of small sausage-like bodies on seafloor. Looks like „sediment rolls“ created by moving clay- sized sediments which start sticking together

[1] All following depths and positions are from the ship. The ROV location is within ±50 m of ship’s position.

14:06	400			passing of wp 2 (66°35.86‘N/17°39.20‘W). T measurement in 0-50 cm depth: background.
15:12	400			passing of wp 3 (66°36.03‘N/17°39.27‘N). T measurement in 0-50 cm depth: background. Still plateau-like area with large ripples from time to time, could also be trawl tracks
15:50	402			bottom water temp. rises from 1.29°C to 1.42 °C. pos.: 66°36.08‘N/17°39.30‘W. may be the southernmost part influence by hydrothermalism??
15:53	404			bottom water temp: 1.46°C, still more or less structureless sediments
16:05	400			lost bottom sight, rise to find head weight
16:15	400			bottom sight again, continue to wp 4
16:20	383			first sights of hydrothermal structures: small depressions (1-2 m) due to dissolution of anhydrites below seafloor? white patches in background pos.: 66°36.25‘N/17°39.26‘W
16:23	400			first large white patch on a smooth seafloor (anhydrite or bacterial mat?), 2-3 m long, 1-2-m wide, several other patches in vicinity
16:28	400			blocky material on seafloor, probably indurated sediment set free by dissolution below seafloor
16:31	398			a lot of pock marks (fluid escape structures?)
16:34	395			blocks of white material (probably dissolving anhydrite chimneys)
16:36	395			near wp 4 (66°36.25‘N/17°39.26‘W)
16:50	395			blocky material coverey by sediment
17:00	380			sonar measurement, ROV 18 m above seafloor, reflections in sonar are interpreted as chimney heads, however they could not be ground-truthed. ROV is approximately right beneath the ship. Ship’s pos.: 66°36.23‘N/17°39.25‘W
17:10	380			sonar measurement, ROV 6 m above seafloor
17:12	390			ROV is drifting to SE, pock marks or holes of digging benthos
17:14	387			large collapse structure, some meters across
				greenish sediment in center surrounded by whitish material, small chimneys at its rim. pos.: 66°36.25‘N/17°39.27‘W
17:16	389			some white patches (anhydrite?) on smooth ground surrounded by orange stained sediments (Fe oxyhydroxides?), small (inactive?) chimneys small elongate hills with circular collapse structure. pos.: 66°36.25‘N/17°39.28‘W, ROV is probably drifted to SE of ship
				From 17:14 – 17:18 (on tape 2/2 from 0:24:00 to 0:28:00): this part is most representative of the southern Grimsey field!!
17:20-17:25				preparation of T lance
17:25	395			gas bubbles are store in sediments and are released when ROV pushes T lance into the seafloor
17:26	394			T measurement near active diffuse vent, area is characterized by white patches, pock marks and gas bubbles rising from the sediment when touched by the ROV
18:00	389			end of ROV dive, start of heaving
19:15				ROV on deck, end of station

Dive Nr. 7 (Station 514ROV)

This dive was carried out in the central Grimsey hydrothermal field. It started at its southern tip at 66°36.30‘N and 17°39.25‘W in 385 m water depth and ended at 66°36.46‘N / 17°39.31‘W after about 5 hours diving. The most important result of this dive is that the central field consists of one large mound at its northern part near the end of the dive. This mound is some tens of meters long, about 10-20 m wide, NE-SW striking, and 5-10 meters high. The mound is covered by anhydrite talus of sand to block-size suggesting that it is made up of detritus from dissolving anhydrite chimneys. It is topped by four active anhydrite chimneys venting clear hydrothermal fluid. The chimneys form pillar-like structures topped by single, delicate spires or by beehive structures (Fig. 5.5). Fluids emanate from the spires and all over the beehives. One sample was taken from a beehive with the ROV’s manipulator arm. The sample totally consists of anhydrite and will be used for microbiological analysis.

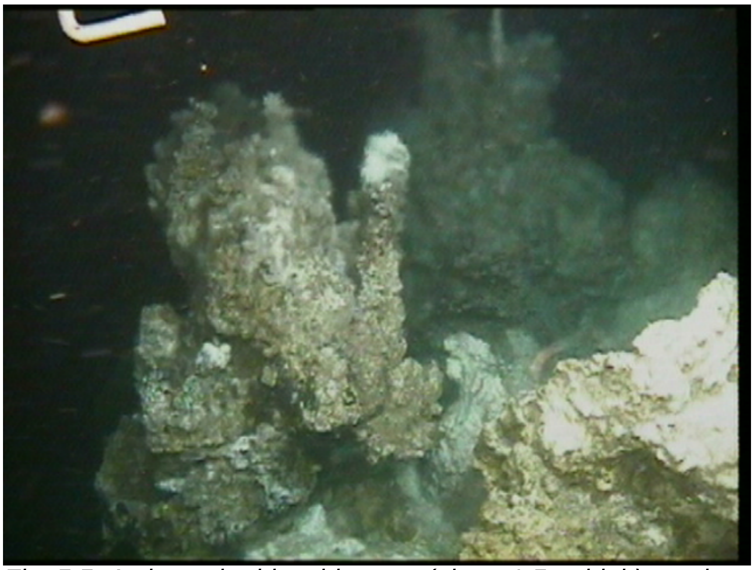


Fig. 5.5: Active anhydrite chimneys (about 1.5 m high) topping the large mound in the northern part of the GHF. Clear fluids emanate from the delicate spires and diffusely all over the chimney structures. Photograph taken during ROV dive 514.

Such a mound was only once found during the dive with the ROV zigzagging through the field. The ship’s track can be seen in Fig. 5.3. However, the deployment configuration of the ROV was such that the ROV can only diviate ±30 m from the ship’s position. Therefore, most of the field has been surveyed during dive 514. In the vicinity of the mound numerous anhydrite patches some meters in diameter appear on the seafloor. They are surrounded by diffuse venting of clear fluids. Furthermore two inactive anhydrite chimneys on a small mound occur near the large active mound. The whole structure is about 2 m high and is in a state of disintegration.

In contrast to the rugged morphology in the northern part of the field, its southern part is characterized by smooth elongate hills 1-2 m high topped by white patches probably consisting of anhydrite. These patches are covered by Fe-oxyhydroxide-containing sediment at their edges (Fig. 5.6). The hills are sometimes topped by single, active anhydrite chimneys. Two specialities of this area are numerous depressions cm to meters in diameter and nodule-like deposits (Fig. 5.7). The depressions could reflect anhydrite dissolution at depth, the nature of the nodule-like deposits remains unknown.

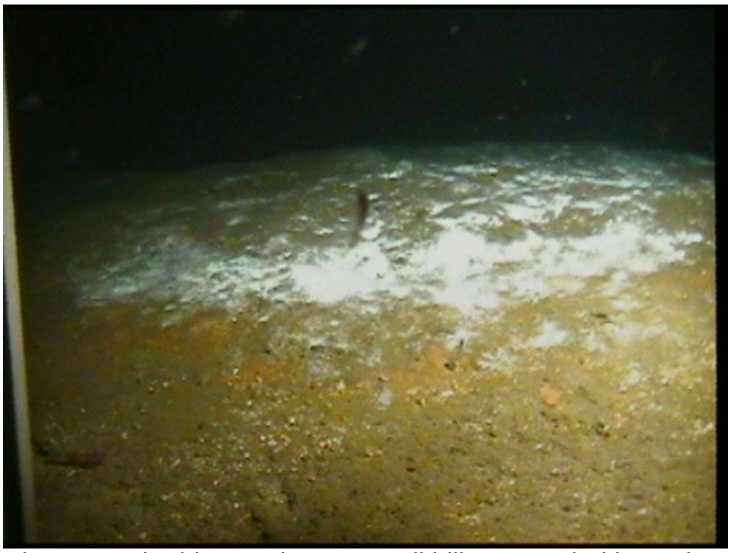


Fig. 5.6: Anhydrite patch on a small hill surrounded by stained sediments (Fe oxyhydroxides) south of the large mound of the GHF. Photograph taken during ROV dive 514. Length of the patch is about 2 m from left to right.

The ROV Cherokee is equipped with a sonar device (325 kHz and 675 kHz) which measures in horizontal direction and is able to map seafloor structures up to 300 m ahead of the ROV. Two sonar profiles were taken at 66°36.30‘N / 17°39.30‘W and 66°36.36‘N / 17°39.31‘W (ship’s position). One such profile consisted of 4 measurements 20 m, 15 m, 10 m, and 5 m above seafloor. The ROV was heading 45±10° N in all measurements. In both sonar profiles mound-shaped structures were detected starting as small hills 20 m above ground and becoming bigger closer to the seafloor (Fig. 5.8). However, only at the northern measurement (66°36.36‘N – see above) could this mound be ground-truthed. It is suggested that the structure seen in the sonar at the northern field represent the mound with the active chimneys described above. The structure at the southern field, which was not ground-truthed could be due to the possibility that the ROV was not in a horizontal position but facing down to some degree during the measurement. This way, even a flat seafloor would appear as a rugged structure in the sonar record.

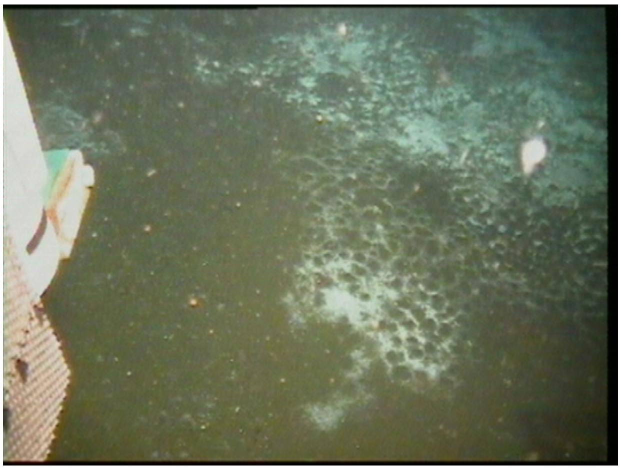
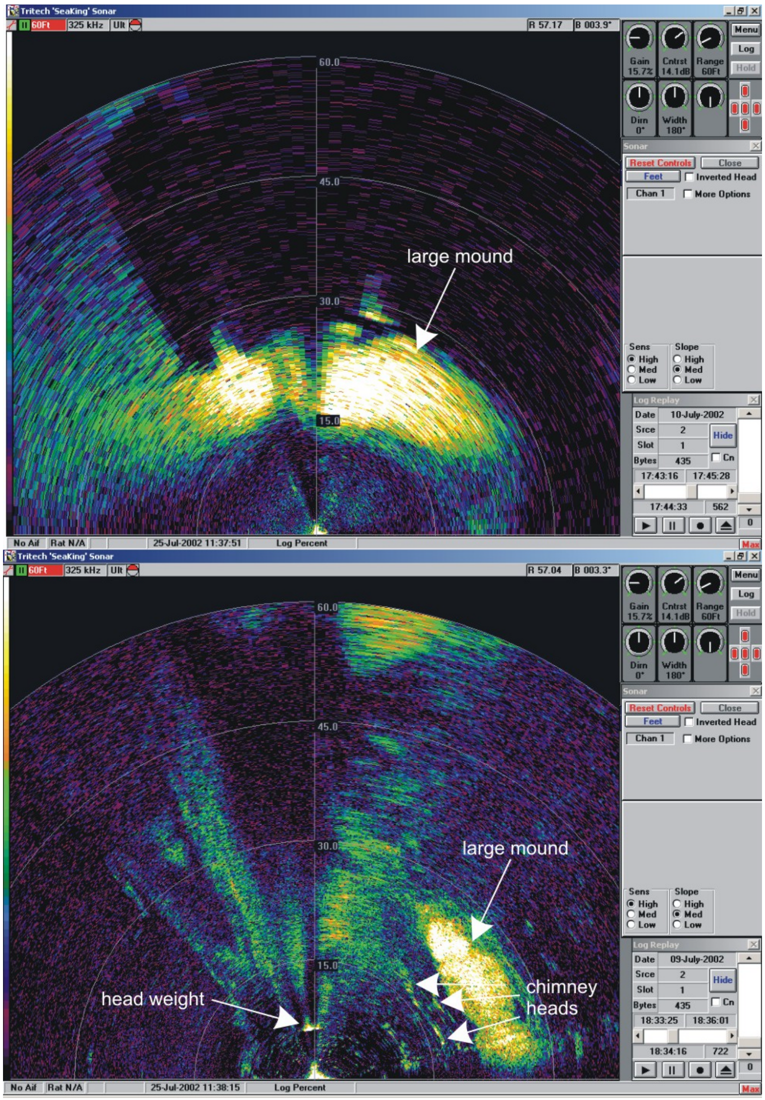


Fig. 5.7: Nodule-like deposits in the central Grimsey hydrothermal field embedded by anhydrite. The „nodules“ are probably hydrothermally altered sediment. Photograph taken during ROV dive 514. Length of picture is about 2-3 m in the foreground.



<u>Fig. 5.8:</u> Sonar measurements carried out by ROV Cherokee. Position of the ROV is always in the middle of the lower horizontal margin of the picture.

Above: central GHF with large mound 15 m ahead of ROV which headed NE and stayed 10 m above seafloor. Position of ship was: 66°36.36‘N/17°39.31‘W, 375 m water depth. The mound is about 50 m long and 15 m wide and more than 10 m high. There are no signals behind the mound suggesting that the mound shields the sonar beams which is only possible if the ROV stays more or less horizontal.

Below: southern GHF with a small mound and a number of chimneys. The head weight was fixed to the lower end of the wire on which the thether of the ROV was attached. It was about 7 m ahead of the ROV which was heading NE and stayed 14 m above ground. Position of the ship was: 66°36.24‘N/17°39.24‘W, 369 m water depth. With this configuration of the sonar data it is posiible to map the relative positions and size of chimneys and mounds in the hydrothermal field.

Dive Log

Date:	July 10, 2002
Time:	14:20 – 20:50 UTC
Depth Range:	385 - 415 m
Location:	northern Grimsey hydrothermal field

Time	Depth (m)	Heading	Position	Comments[2]
14:20				begin of station
15:00	20			tests in water, afterwards lowering to seafloor
15:59	395			ROV 20 m over ground, sonar measurement
16:05	396			ROV 15 m over ground, sonar measurement
16:10	391			ROV 10 m over ground, sonar measurement
16:28	400			ROV 5 m over ground, sonar measurement
16:32	396			bottom view, TUBAF DV tape on pos: 66°36.27‘N/17°39.29‘W seafloor sediment covered
16:35	396			circular depression about 1 m across (collapse structure?), white patches, lots of shrimps
16:36	396			small hill covered by anhydrites which are surrounded by reddish-orange stained sediments (Fe oxyhydrides), small cross-like active anhydrite chimney
16:40	400			field of black nodule-like precipitates
16:43	393			reddish-orange stained sediments below normal sediment
16:45	392			lost of bottom view
17:00	394			bottom view
17:02	394			lost of bottom view
17:07	395			bottom view: sediment covered, no hydrothermal precipitates
17:09	398			crust-like material on sediments
17:12-17:20	391			small ridge 1-2m high striking NW with white patch on top
17:21	393			circular depressions on topof above-ment. ridge
17:26	396			chimney remnants, white patches of anhydrite, bacterial mats? still on the small ridge
17:30	403			lost bottom sight
17:37	400			bottom sight again
17:38	397			small chimney structure just starting to grow, clear hydrothermal fluid is venting, no boiling
17:52	393			T measurement in sediment 0-50 cm; 3.5 – 31°C
18:29	395			begin sonar survey at 66°36.36‘N/17°39.28‘W, 20 m above ground, heading NE
18:47	399			sonar survey 15 m above ground, heading NE pos. 66°36.34‘N/17°39.35‘W
18:52	395			sonar survey 10 m above ground, heading NE pos.: 66°36.37‘N/17°39.30‘W
18:57	401			sonar survey 5 m above ground, heading NE pos.: 66°36.34‘N/17°39.38‘W
19:00	391			normal hemipelagic sediment
19:09	392			crust-like formations (indurated sediment?)
19:16-19:20	390-405			solitude chimneys on small ridge about 1-2 m high
19:30	397			circular depressions 1-2 m across
19:32	398			ROV is being dragged behind the ship, smooth sedimented seafloor, probably on a small ridge, white patches appear in a depression, vigerousl diffuse venting all over the white patch (ca. 2-3 x 1 m)
19:40	396			more anhydrite debris, this is the foot of the large mound charakterizing the central hydrothermal field
19:42	396			top of the large central mound which is about 10 m high being topped by

[2] All following depths and positions are from the ship. The ROV location is within ±50 m of ship’s position.

– 19:52				4 active anhydrite chimneys. the slope of the mound is covered by anhydrite debris, rather steep slope compared to the smooth sedimented ridges found so far, anhydrite chimney are massive, pillar-like or behive-like, pos. 66°36.44‘N/17°39.24‘W, ROV is actively moving therefore it may be ± below the ship
19:50	399			sampling an active chimney with beehive structure pos.: 66°36.47‘N/17°39.35‘W
20:03	396			end of ROV dive, start hieving to deck
20:50				on deck, end of station

Dive Nr. 8 (Station 518ROV)

The objective of this dive was to map the seafloor at the intersection of a hypothetical NW-SE fault structure with the west slope of the N-S ridge at 66°36.7‘ N and 17°40.5‘W (see Fig. 2.5 and 5.3). It should be analyzed if there is any hydrothermal activity or hydrothermal precipitates bound to this intersection.

The main result of this dive is that no hydrothermal activity nor precipitates could be found in the area investigated by the dive. The seafloor is covered by more or less structureless sediments. At some parts old rocks occur which are covered by sediments and overgrown by benthic fauna. These rocks may derive from the upper parts of the N-S ridge and may be of volcanic origin. Strong currents are marked by ripple structures mainly striking NW-SE. In some parts ripple structures could be mixed with trawl tracks.

Despite the strong sediment cover, a vertical wall being 2-3 m high marks the western slope of the N-S ridge between about 66°36.64‘ and 66°36.70‘N at 17°40.40‘W roughly striking N-S. Due to the high sedimentation rate in this area which smooths out every structure in time this vertical wall is probably an expression of active extensional tectonics. Normal faults with some meters offset are also reported from the Husavik peninsula where they are also ascribed to active earthquake-producing tectonics (Gudmundsson et al., 1993). Large blocks of rocks or consolidated sediments have broken off the wall and lie at its foot. All rocks are covered by benthic organisms like sponges. A sample was taken of the wall, it consists of indurated hemipelagic clay and Fe oxyhydroxide crusts covered by Mn oxides.

No features but structureless hemipelagic sediment cover the seafloor east of the steep west slope as was found during the second, eastbound part of the dive (Fig. 5.3).

Dive Log

Date:	July 11, 2002
Time:	12:40 – 16:49 UTC
Depth Range:	384 - 430 m
Location:	intersection of hypothetical NW-SE structure with N-S ridge at its western slope

Time	Depth (m)	Heading	Position	Comments[3]
12:40				begin of station, lowering ROV to 20 m to perform tests
13:18	395			first sonar survey 20 m above ground, heading NE, distinct slope in E direction, about 50 m ahead
13:27	397			bottom sight, normal hemepelagic sediment pos.: 66°36.71‘N/17°40.48‘W
13:34	405			sometimes benthic macrofauna like sponges, anemones, some debris on sediment surface (indurated sediment or volcanic debris from higher on the N-S ridge??)
13:40	392			large trawl tracks
13:44	400			second sonar survey on ground heading S pos.: 66°36.69‘N/17°40.50‘W
13:56	398			T measurement: only background values try to take a sample: only sediments: failed
up to 14:18	389			structureless hemipelagic sediment, sometimes current ripples, sometimes trawl tracks, sometimes benthic macrofauna, no hydrothermal precipitates or activity
14:28:	393			small vertical wall about 0.5 m (like an escarpment)
14:34	391			vertical wall now about 2-3 m high, rocks popping out of the wall, orientation: ± N-S, rocks are overgrown by biology and partly covered by

[3] All following depths and positions are from the ship. The ROV location is within ±50 m of ship’s position.

				sediment vertical wall occuring despite the very high sedimentation rate which smooths everything out may be an expression of very recent extensional tectonics
14:44	386			still on the wall, taking a sample, put into the plastic liner pos.: 66°36.63‘N/17°40.39‘W
14:51	395			still on wall, large blocks 2-3 m across are lying in front of the wall and are probably broken off of it blocks are largely covered by sponges and soft sediment, blocks may also consist of indurated sediment
15:03	400			still on wall, appearance is the same
15:07	390			still on wall but on smoother part taking a sample (that turned out on deck to be indurated sediment and Fe oxyhydroxide crust) sample was put into the metal basket pos.: 66°36.72‘N/17°40.38‘W
15:19	391			left the wall, now on flat sedimented ground
15:22	388			ship starts to drift eastward, only hemipelagic sediments on seafloor, no structures except sometimes large trawl tracks and macrobenthos, no signs of hydrothermalism whatsoever, shallowest point: 384 m
16:49	390			end of dive, start hieving
17:30				ROV on deck, end of station

5.2 Temperature measurements at the sediment-water interface (M. Heesemann, H. Villinger)

During the R/V Poseidon cruise PO-291, first field tests of a high resolution temperature probe, which can be mounted to the “Cherokee” remote operated vehicle (ROV) of the University of Bremen, were performed. The temperature probe consists of a lance, which houses 8 temperature sensors over an active length of 50 cm, and a data logger. The logger digitizes the analog signal provided by the temperature sensors, and stores the data in its internal nonvolatile memory. Additionally, the data is sent to an external communication interface in order to provide real-time access to the measured data. Using this setup, it is possible to map the small scale temperature distribution in the water-column as well as in the first 50 cm of the sediment-column which can be penetrated by the lance. During PO-291 the temperature distribution of the upper sediment column in the vicinity of the Grimsey hydrothermal field (GHF) was measured along the ROV tracks of the Stations 509, 514, and 518. The locations of the measurements, where the lance successfully penetrated the sediments, are listed in Table 5.1 and displayed in Fig. 5.9.

Station	Pen	Date	Time (UTC)	Duration (min)	Lat*	Long*	Depth* (m)
509	1	09. Jul 02	13:12	4	66° 35.71'	-17° 39.22'	408
509	2	09. Jul 02	14:11	5	66° 35.85'	-17° 39.20'	407
509	3	09. Jul 02	15:18	8	66° 36.02'	-17° 39.29'	406
509	4	09. Jul 02	18:15	16	66° 36.23'	-17° 39.28'	393
514	1	10. Jul 02	17:51	10	66° 36.37'	-17° 39.27'	397
518	1	11. Jul 02	13:53	6	66° 36.70'	-17° 40.52'	406
518	2	11. Jul 02	16:00	1	66° 36.76'	-17° 39.73'	392

*Position and depth of the ship. The ROV is located within ±50m of the ships' position.

Tab. 5.1: Positions of successful temperature measurements in the sediment-column.

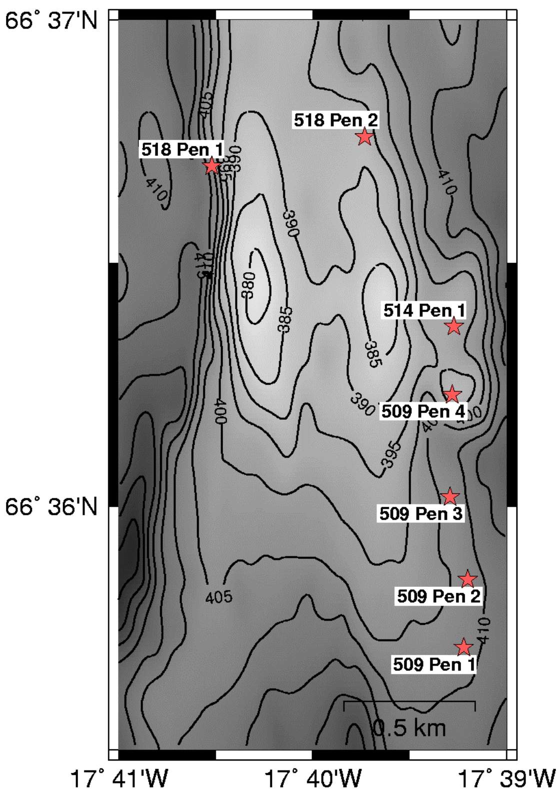


Fig. 5.9: Positions of all successful sediment-column temperature measurements in the vicinity of the Grimsey hydrothermal field which is covered by measurements 509 Pen 4, and 514 Pen 1. The bathymetry is computed based on the single beam echo sounding data recorded during this cruise.

5.2.1 Instrumentation and shipboard operation

The eight **temperature sensors**, which are located at a spacing of about 7 cm in the lance, are P100BB503M thermistors manufactured by Thermometrics. They have a zero-power resistance of 50 kOhms at 25 °C with a tolerance of ?20 %.
The employed **data logger** is a XR-420 T8 produced by the Richard Branker Research Ltd. Using the logger, the resistances of the thermistors are digitized by the internal 24 bit A/D converter and stored as unit-less logger readings at a sampling rate of 10 s. The resolution at a temperature range from –15 °C to 30 °C is better than 0.0005 °C and the typical achieved accuracy is around 0.005 °C. 2 MB of nonvolatile flash memory are used in order to ensure data retention even when the batteries run out. This provides enough memory for 600,000 readings, which can be logged on one set of four 3 V lithium batteries.
During normal ROV operation, the **lance** is located in a **repository** (Figure 5.10) that is attached to the ROV (Figure 5.11). In order to push the lance into the upper 50 cm of the sediment column, it is lowered and locked using the manipulator while the ROV is located well above the seafloor. Thereafter, the ROV is lowered to the seafloor pushing the lance into the sediment. This sequence is chosen, because retaining the ROV on the seafloor causes a cloud of suspended sediments that restricts the sight of the operators, which renders the use of the manipulator more difficult.

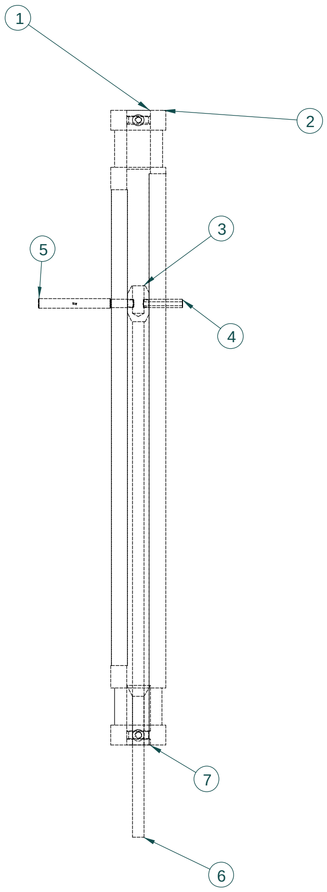
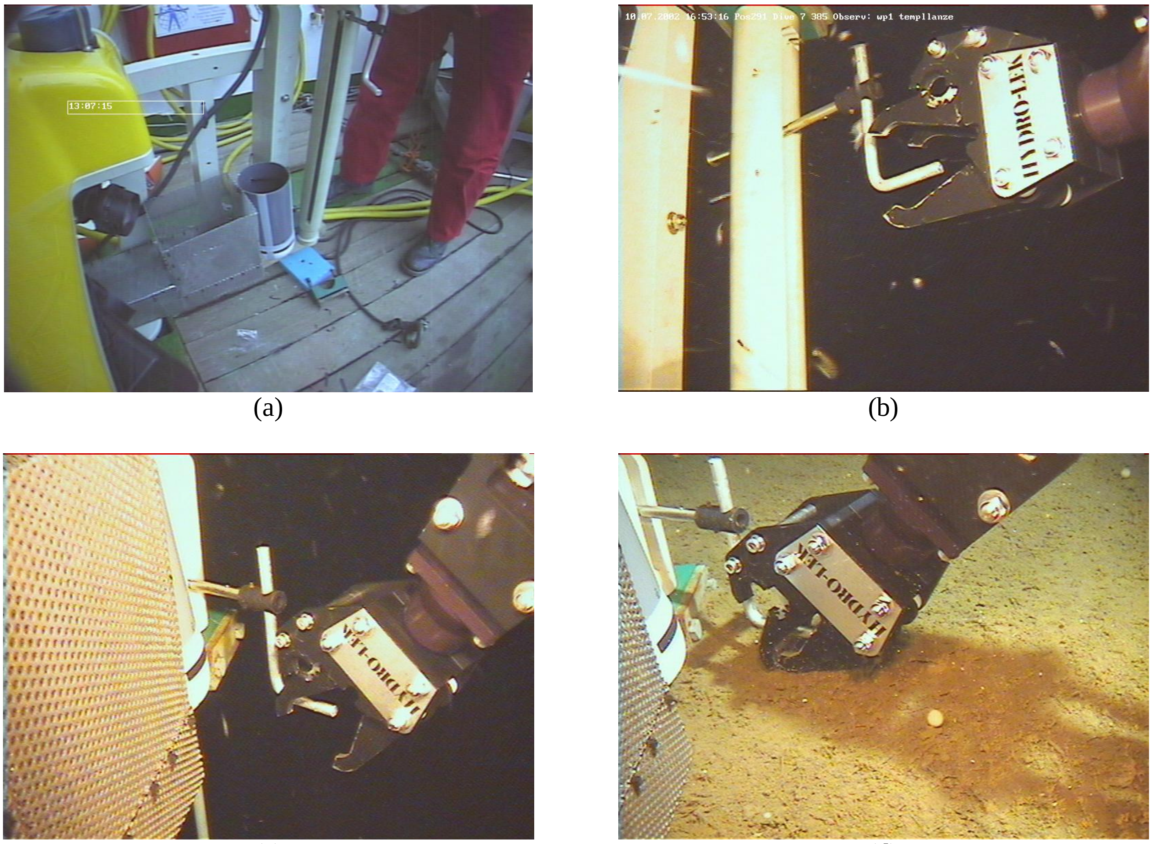


Fig.5.10: Construction details of the lance repository.
Key:

(1) End-cap top
(2) Lance repository
(3) Lance guide and mounting
(4) Cable outlet
(5) Handle
(6) Lance
(7) End-cap bottom

After initial tests, the cable outlet (4) turned out to be mechanically weak, and to cause problems when the lance is pushed out of the repository. Consequently, the opening at the end-cap (1), which was removed, was used as cable outlet during the cruise. (Drawing by Bernd Heesemann)



(a) (b) (c) (d)

Fig. 5.11: Probe Operation: First (a), the lance repository is mounted to a frame which extends to the front of the ROV. In order to lower the lance (b), the lance has to be disengaged from its locking position by pushing the handle to the left. Thereafter, the handle is lowered and fixed (c) at the lowest position using the manipulator. Finally, the lance is pushed into the sediments (d) by landing the ROV on the seafloor.

Additionally, a **miniature temperature logger** (MTL) was attached at the lower end of the lance repository. The MTL is capable of logging temperature data over a programmable time interval without any user interaction. After the measurements, the MTL is connected to a personal computer in order to retrieve the data. The memory of the MTL is sufficient for 18 h of logging at a sample rate of 1 s. Because of their excellent absolute temperature accuracy of less than 0.01 °C, which is achieved by calibration in a high precision temperature bath, the MTLs provide good reference temperatures (Pfender and Villinger, 2002).
The MTL data provides bottom water temperatures, while the lance is located in the sediment column. Furthermore, the MTLs were used to provide a preliminary calibration of the thermistors located in the lance, which could not be calibrated in a high precision temperature bath before the cruise. The calibration was obtained by fitting temperatures measured by the MTL and resistances of the thermistors measured at the same time to the Steinhart-Hart Equation (Steinhart and Hart, 1968). This equation is an empirically developed polynomial which best represents the resistance-temperature relationship of the thermistors used. The reference temperatures were measured in the water column during the ROV dives, and in a bath of hot water which slowly cooled down to room temperature.

5.2.2 Initial results

Figures 5.14-5.20 display the temperature distributions measured at the seven locations which are presented in Figure 5.9 and Table 5.1. The left panel of each figure shows the temperature readings of each thermistor and the MTL during the time of the measurement. The thermistors are labeled with numbers starting from 1 (dark color) for the deepest thermistor up to 8 (bright color) for the thermistor that is closest to the water-sediment interface. During the penetration the measured temperatures slowly approach the temperatures encountered in the sediment. Unfortunately, the duration of most penetrations was not long enough to reach the thermal equilibrium of the lance. The left panel also contains a dashed line, which marks the time at which the state closest to the thermal equilibrium is reached.

The temperatures measured at this time are plotted against the relative depth of the sensors in the right panel of each figure. The depths are relative, since the distance between the thermistors is known, but the total penetration depth of the lance is not exactly known. Gaps in this plot are due to dropouts of the corresponding sensor-channels that occurred during operation. The dashed line in some of the plots in the right panel represents the thermal gradient that is given as a reference in the plots' title. Moreover, the bottom water temperature logged by the MTL is denoted by a triangle at the relative depth of 0 cm.

The measurements are divided into two groups. The first one (Figures 5.14-5.18) with relatively small temperature ranges, shows a curved temperature gradient, which is most likely the result of a transient thermal state. These transient temperature distributions could be raised by a recently increased bottom water temperature, for which evidence was found as illustrated in Figure 5.12.

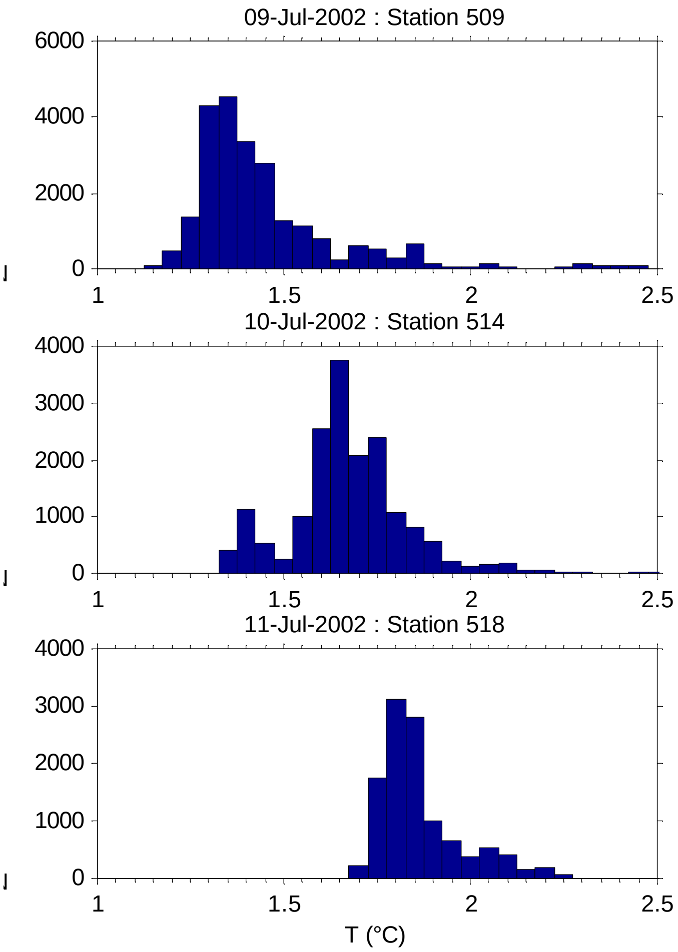


Fig. 5.12: The histograms show the lower temperature range of the three ROV dives in the vicinity of the GHF. The data is recorded using the MTL. The water temperature during all dives was decreasing with increasing depths. Hence, the temperatures presented in the histograms are the temperatures measured when the ROV was close to the sea-floor. Since the variations in sea-floor depth along the ROV tracks are only about 15 m and not strictly decreasing, evidence for increasing bottom water temperatures is given. This increase takes place at a rate of approximately 0.2°C per day.

Further evidence for an increase in bottom water temperatures is given by the surface water temperature that was measured using the shipboard thermometer. During the mapping of the bathymetry of the region around the GHF on 28-Jun-2002 and 29-Jun-2002 the surface temperatures were more than 2°C colder than the surface temperatures measured during the ROV dives which took place about 10 days later. Based on these observations, a finite element model simulating the influence of an increasing bottom water temperatures on the temperature distribution in the sediment column was set up (Figure 5.13).

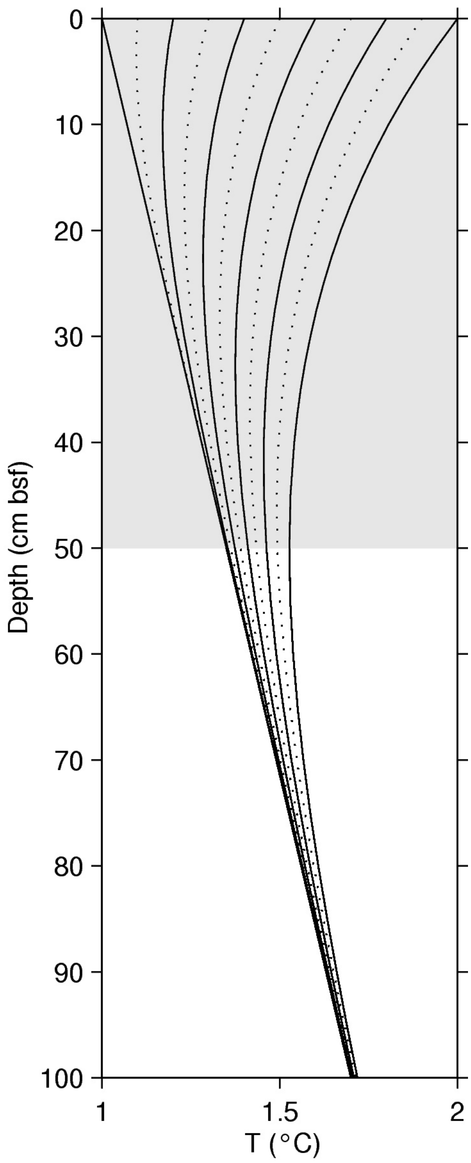


Fig. 5.13: Influence of increasing bottom water temperatures on the temperature distribution of the first 100 cm of the sediment column computed using a finite element model. The straight line towards the left represents the steady-state condition that results from an initial bottom water temperature of 1 °C, and a heat-flux of 0.7 W/m². The lines towards the right show changes in the temperature distribution of the following 5 days in steps of 12 h. These changes are due to an assumed increase of bottom water temperatures at a rate of 0.2 °C per day. Furthermore, a thermal conductivity of 1 W/(m K), and a product of density and heat capacity of $3?10^6$ J/(K m³) are assumed as the physical parameters of the sediment column. The shaded area denotes the depth interval that is accessible using the described temperature probe.

The measurements of the ROV Station 509 (Figures 5.14 – 5.16) show decreasing temperatures in the first 20 cm of the sediment column, and increasing temperatures at greater depths. Similar behavior is shown by the curves modeled for an increasing bottom water disturbance over 1-3 days. At ROV Station 514, which was performed two days later, only negative temperature gradients, which decrease with increasing depth, were measured (Figures 5.17 – 5.18). This is similar to the temperature distribution simulated for a bottom water temperature that is increasing over a time interval of more than four days.

The second group (Figures 5.19 – 5.20) is measured very close to hydro-thermal vents and is characterized by extremely high temperatures resulting in thermal gradients which are more than an order of magnitude higher than the estimated disturbances due to changes in bottom water temperature.

Transient temperature distributions

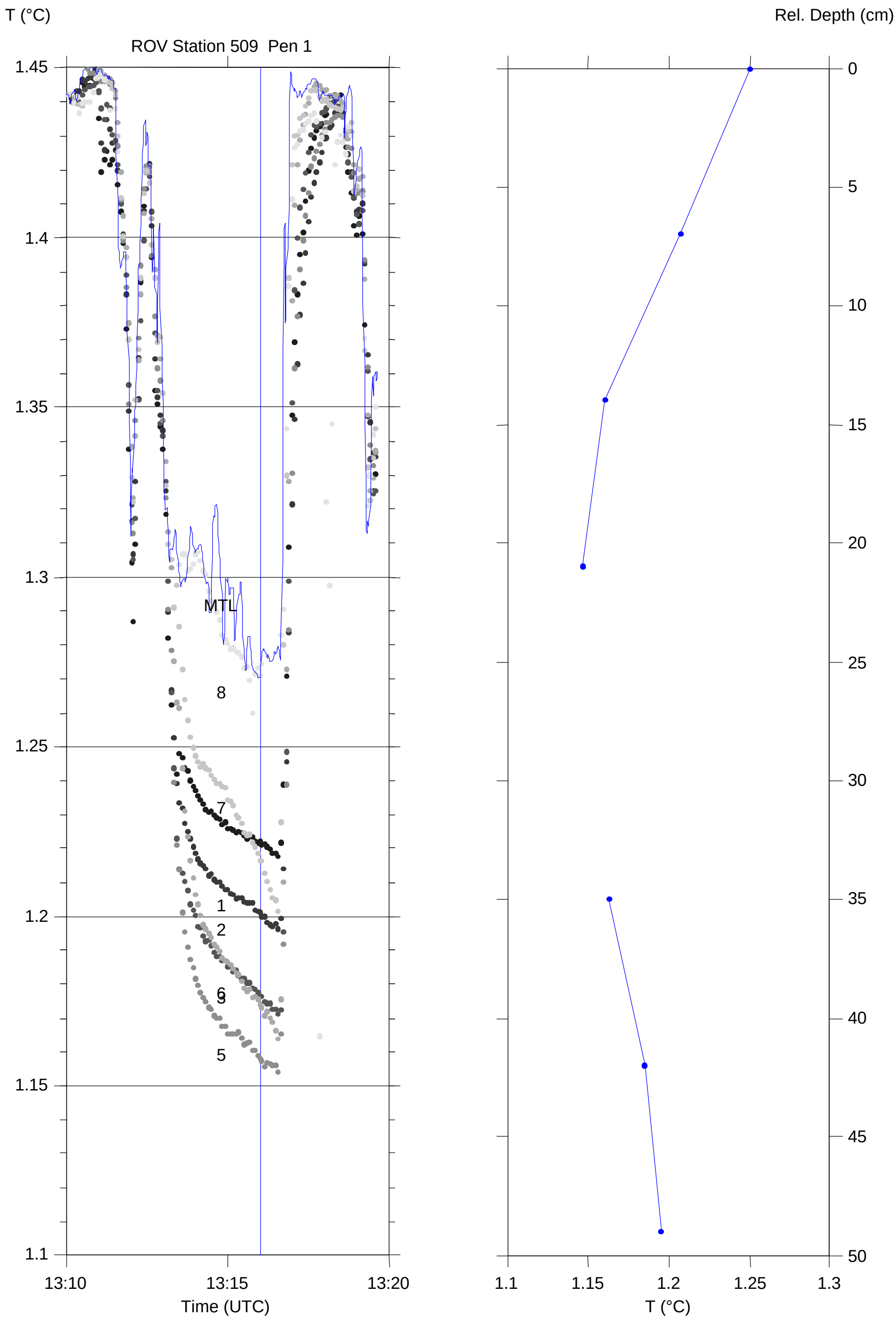


Fig. 5.14: 509 Pen 1: Temperature distribution indicates a recent rise of the bottom water temperature.

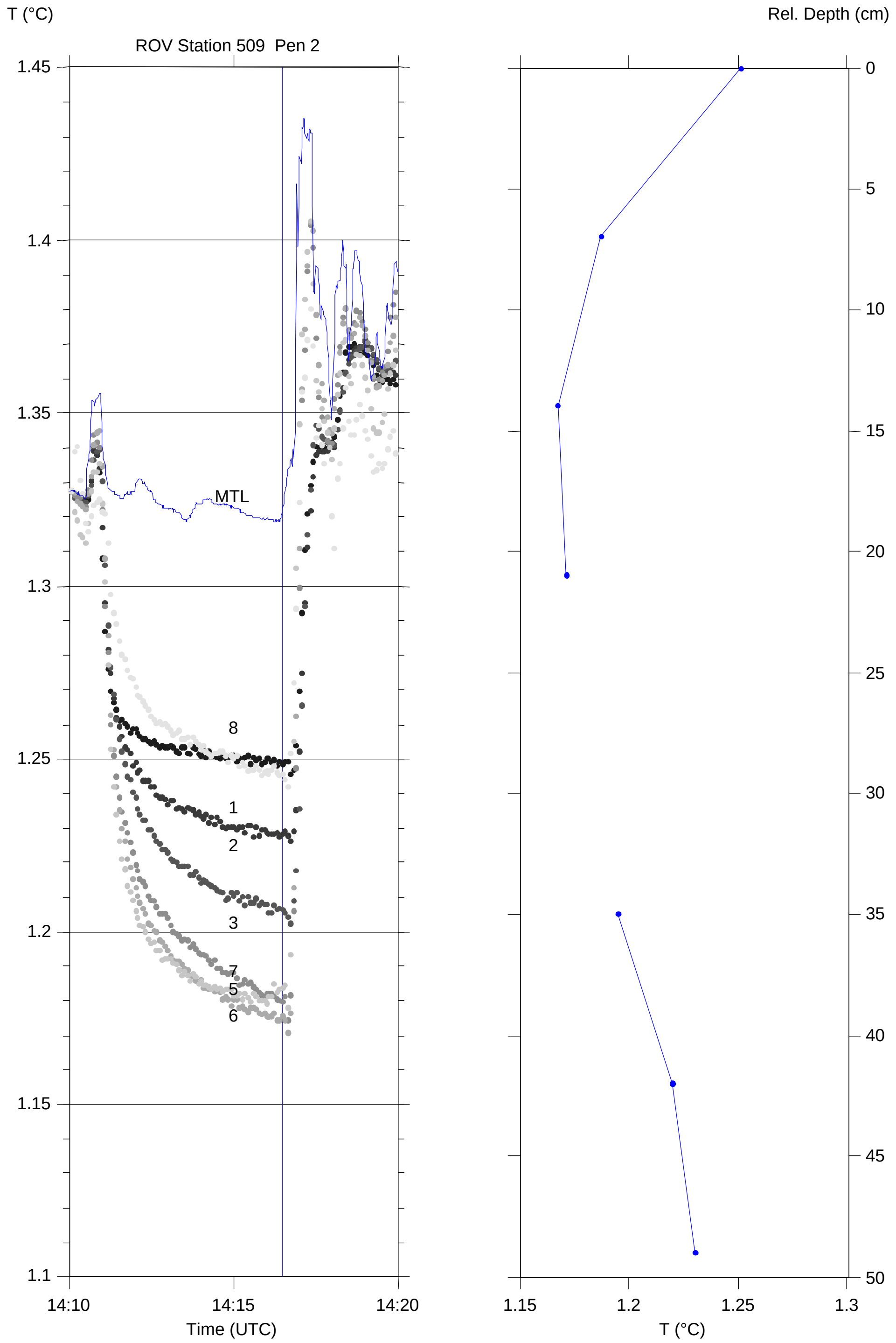


Fig. 5.15: 509 Pen 2: : Temperature distribution indicates a recent rise of the bottom water temperature.

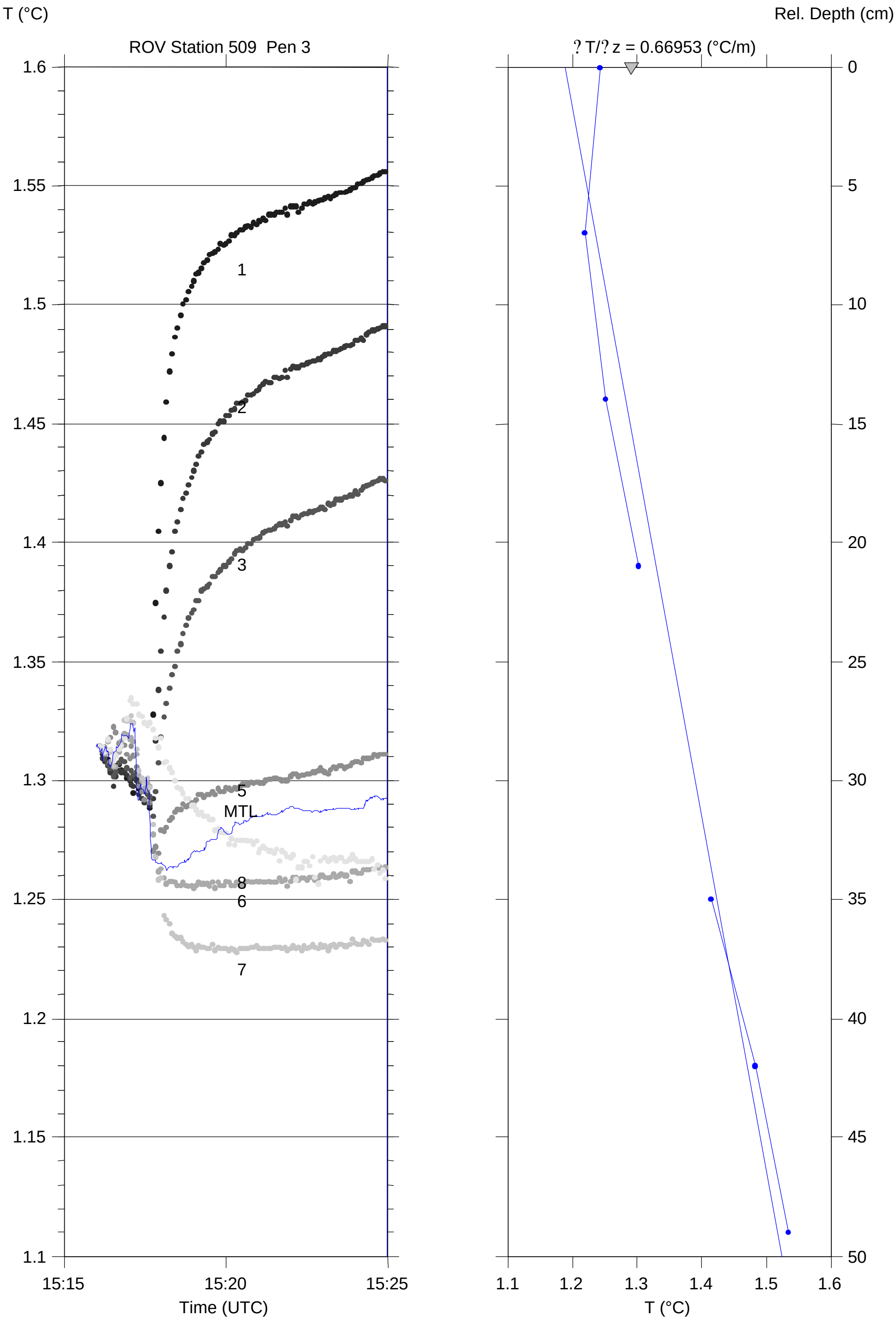


Fig. 5.16: 509 Pen 3: Temperature distribution indicates a recent rise of the bottom water temperature. The temperature at the relative depth of about 50 cm is about 0.3 C higher than in both of the previous measurements indicating an increased heat-flux.

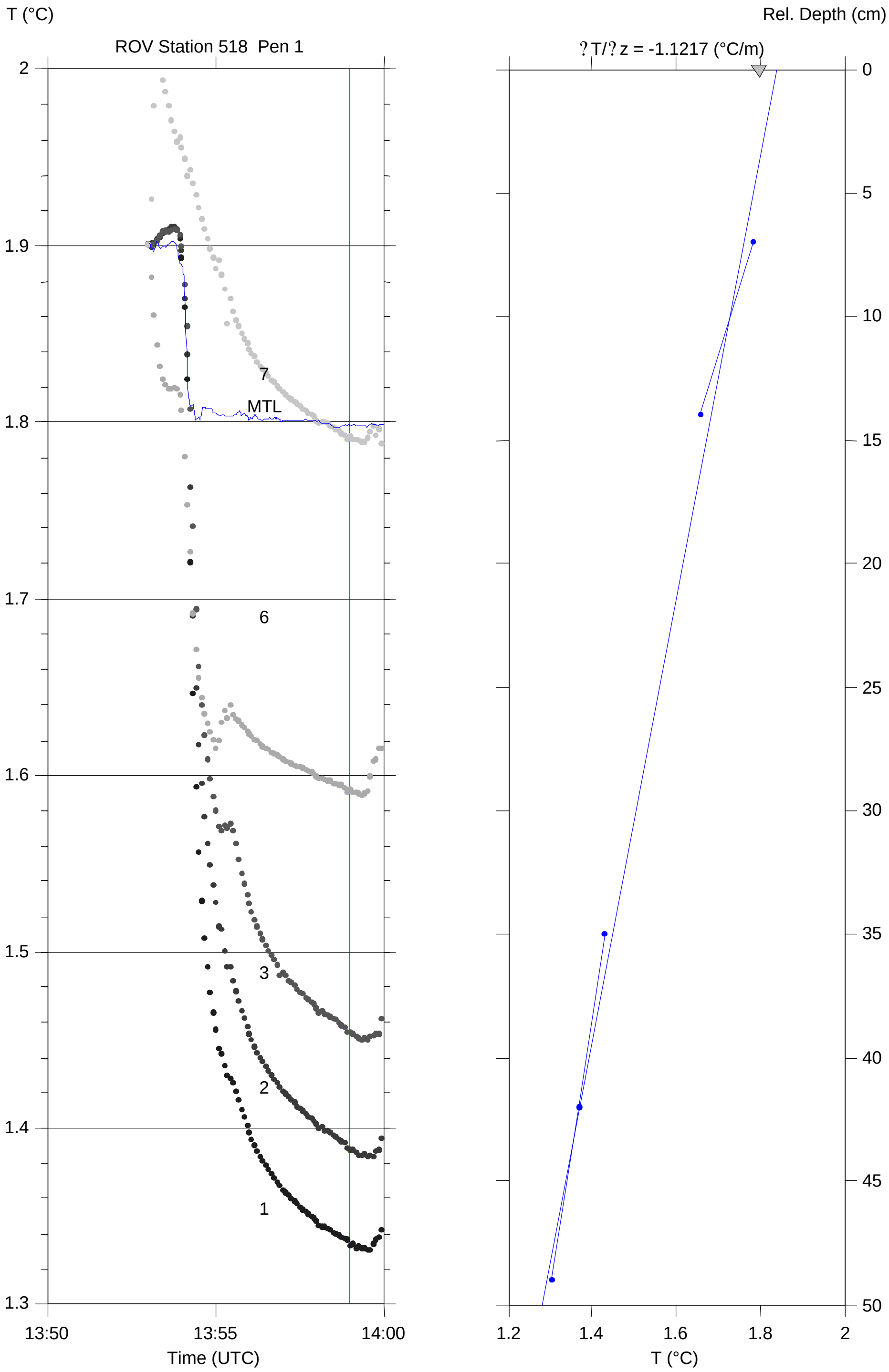


Fig. 5.17: 518 Pen 1: Temperature distribution indicates a rise of the bottom water temperature disturbing the whole measured depth interval.

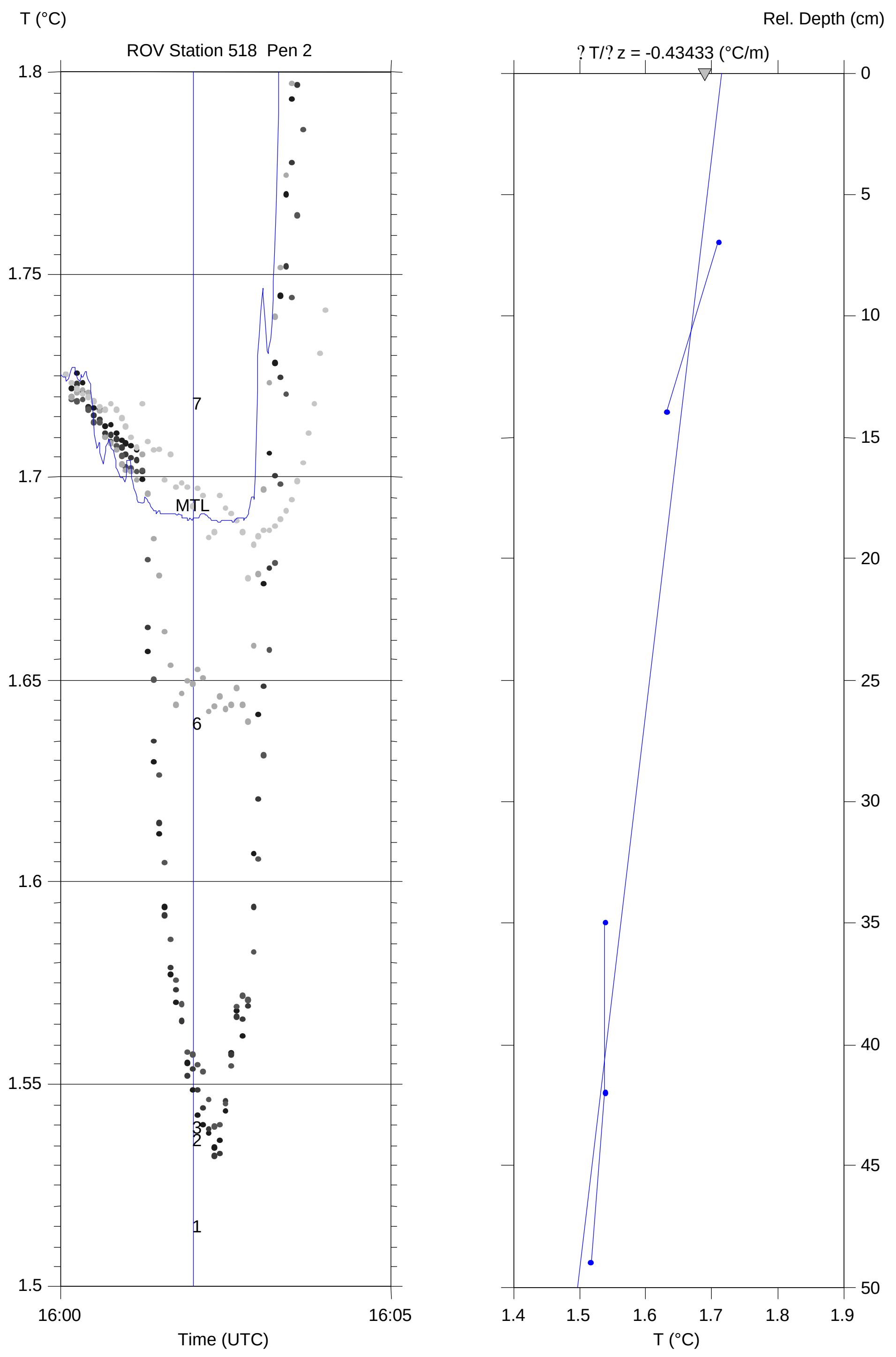


Fig. 5.18: 518 Pen 2: Temperature distribution indicates a rise of the bottom water temperature disturbing the whole measured depth interval.

High temperature gradients

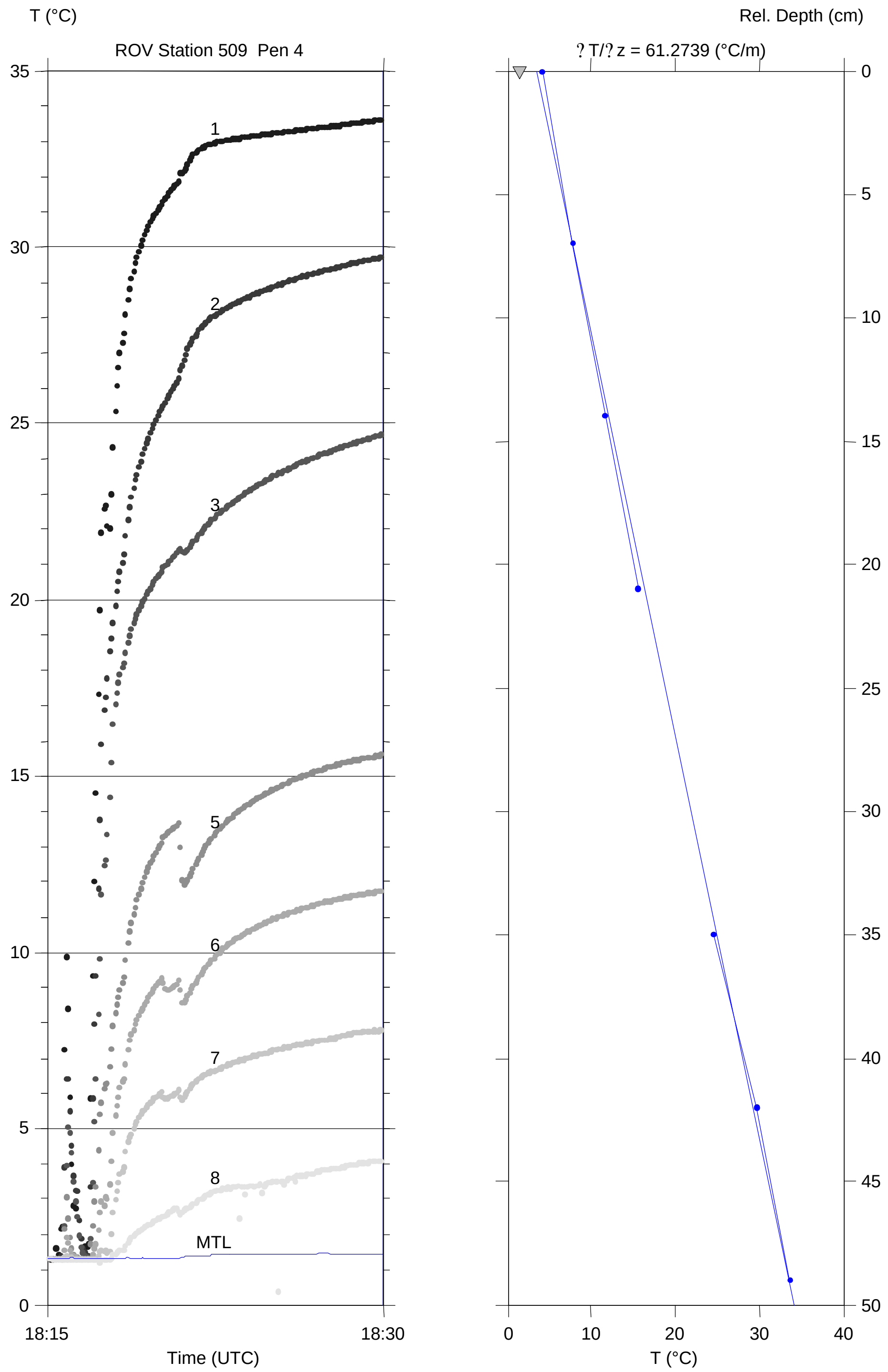


Fig. 5.19: 509 Pen 4: High temperature gradient measured close to an hydrothermal vent. The disturbances that took place around 18:20 are probably due to ROV movements.

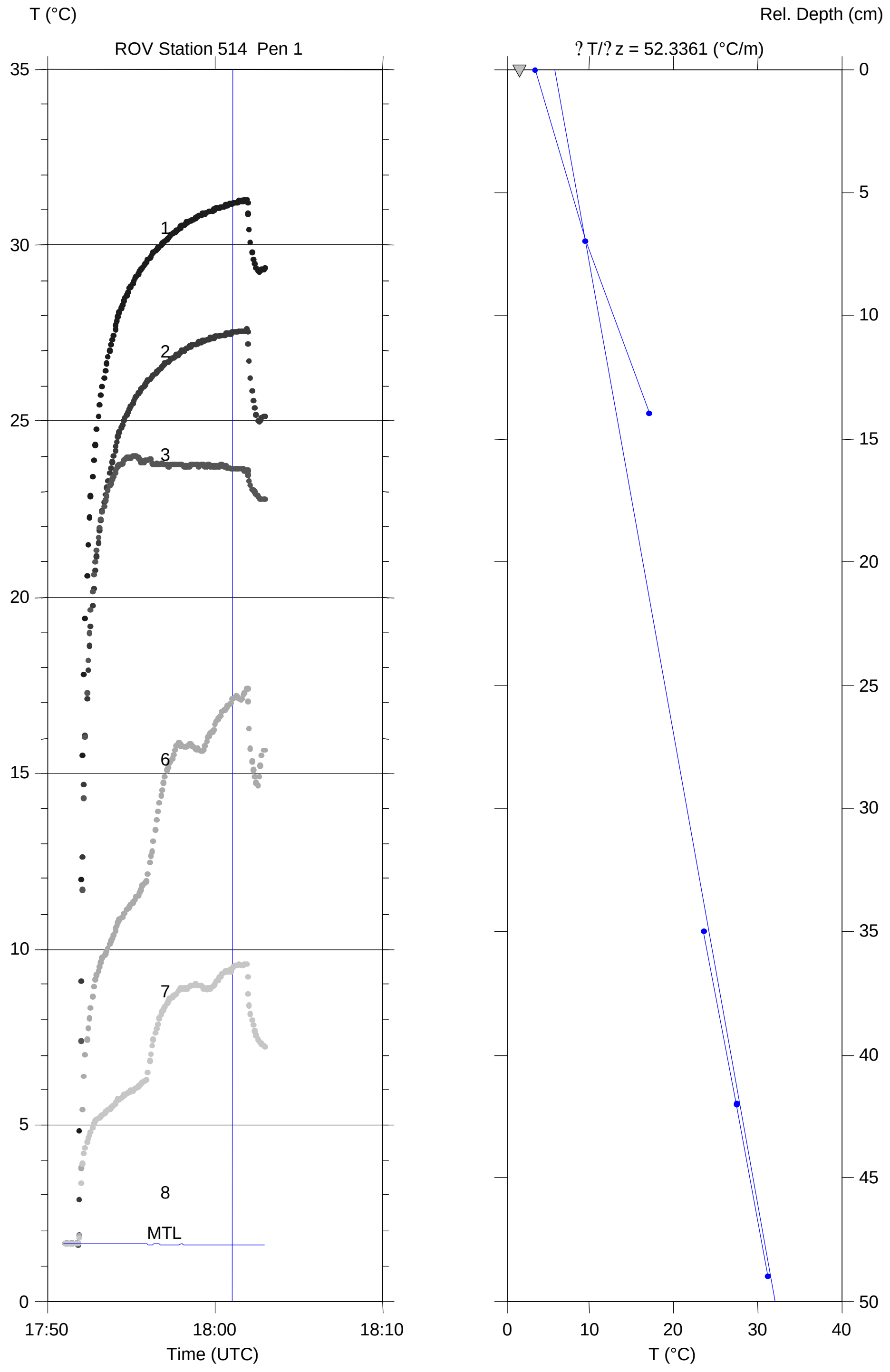


Fig. 5.20: 514 Pen 1: High temperature gradient measured close to an hydrothermal vent. The disturbances that took place around 17:55 are probably due to ROV movements.

6. Rock Sampling Stations

Station	Latitude/Longitude	Depth	Sample descriptions and samples
435DS	66°36,17'N/17°39,01'W to 66°36,17'N/17°39,61'W	416m to 390m	Mud and worms
436DS	66°36,14'N/17°39,11'W to 66°35,99'N/17°39,28'W	417m to 400m	Mud
437DS	66°37,66'N/17°47,93'W to 66°37,38'N/17°48,06'W	464m to 390m	Mud
438DS	66°37,29'N/17°44,75'W to 66°37,60'N/17°45,33'W	472m to 370m	Mud
442DS	66°35,83'N/17°40,22'W to 66°36,07'N/17°40,89'W	401m to 420m	One old rock
443DS	66°36,00'N/17°39,80'W to 66°36,39'N/17°40,75'W	393m to 410m	Mud
444DS	66°36,58'N/17°40,13'W to 66°36,76'N/17°40,90'W	382m to 410m	Mud
445DS	66°37,04'N/17°40,05'W to 66°37,08'N/17°40,26'W	389m to 390m	Mud
446DS	66°36,66'N/17°41,14'W to 66°36,75'N/17°41,18W'	400m to 402	Mud
447DS	66°36,62'N/17°40,39'W to 66°36,57'N/17°39,71'W	380m to 383m	Empty
455DS	66°38,95'N/18°02,83'W to 66°39,01'N/18°01,39'W	205m to 230m	Mud, some old rocks
465DS	67°01,74'N/18°42,94'W to 67°01,81'N/18°43,10'W	170m to 127m	-1: 10x20x5cm, basalt with glass, vesicular -2: 10x10x4cm, basalt with glass, lightly covered with organisms, vesicular
466DS	67°00,91'N/18°42,42'W to 67°01,08'N/18°42,02'W	247m to 313m	-1: 20x10x5cm, basalt without glass, vesicular -2: 10x10x5cm, basalt with glass, vesicular -3: 7x7x7cm, basalt without glass, vesicular
467DS	67°00,64'N/18°43,45'W to 67°00,75'N/18°43,08'W	324m to 338m	-1: 30x20x20cm, pillow basalt with glass, fresh, glass splitted in extra bag -2: 15x10x5cm, basalt with glass, vesicular
468DS	67°00,50'N/18°44,94'W to 67°00,62'N/18°44,50'W	350m to 294m	-1: 10x5x5cm, basalt with glass, vesicular -2: 5x5x5cm, basalt, vesicular
469DS	67°00,78'N/18°44,99'W to 67°00,85'N/18°44,76'W	346m to 320m	-1: 5x5x3cm, basalt with glass, vesicular
470DS	67°01,38'N/18°44,93'W to 67°01,54'N/18°44,48'W	341m to 289m	-1: 15x10x10cm, basalt, vesicular, lightly covered with organisms -2: 5x5x3cm, basalt with glass, vesicular, covered with organisms -3: 10x5x5cm, basalt, vesicular, covered with organisms
472DS	67°03,31'N/18°45,48'W to 67°03,35'N/18°45,91'W	236m to 171m	-1: 10x8x8cm, old basalt, no glass, covered with varied biological organisms -2: 5x5x5cm, old basalt, no glass, covered with varied biological

			organisms
473DS	67°03,49'N/18°43,44'W to 67°03,55'N/18°43,57'W	177m to 145m	-1: 20x10x10cm, old basalt, no fresh glass, covered with organisms -2: 10x8x8cm, old basalt, no fresh glass, covered with organisms
474DS	67°02,99'N/18°41,82'W to 67°03,08'N/18°42,05'W	276m to 216m	-1: 10x8x5cm, basalt with glass -2: 5x5x5cm, basalt with glass
475DS	67°02,83'N/18°41,90'W to 67°02,84'N/18°42,34'W	283m to 121m	-1: 15x15x10cm, basalt, thin glass rim, vesicular, lightly covered with organisms -2: 10x8x8cm, basalt, vesicular
476DS	67°01,94'N/18°42,07'W to 67°01,88'N/18°42,23'W	236m to 244m	Gravel
478DS	66°49,15'N/18°43,91'W to 66°49,18'N/18°43,11'W	637m to 642m	Empty
479DS	66°50,12'N/18°44,08'W to 66°50,06'N/18°43,62'W	632m to 426m	One dropstone
480DS (same as 479DS)	66°50,00'N/18°44,22'W to 66°50,10'N/18°44,79'W	594m to 668m	Empty
481DS	66°50,89'N/18°42,15'W	587m	Empty
482DS	66°50,97'N/18°42,31'W to 66°51,29'N/18°41,37'W	584m to 465m	Empty
483DS	66°52,01'N/18°43,98'W to 66°51,88'N/18°43,09'W	574m to 557m	-1: 10x10x10cm, basalt, no glass, lightly covered with organisms
484DS	66°52,93'N/18°45,09'W to 66°52,81'N/18°44,70'W	513m to 520m	-1: 10x5x5cm, basalt with glass, vesicular
485DS	66°53,92'N/18°44,88'W to 66°53,73'N/18°44,73'W	460m to 451m	-1: 10x10x10cm, fresh basalt with glass -2: 5x5x5cm, fresh basalt with glass -3: 5x5x5cm, fresh basalt with glass
486DS	66°55,04'N/18°45,53'W to 66°54,95'N/18°45,18'W	473m to 428m	-1: 15x10x10cm, tube, fresh basalt with glass -2: 5x5x5cm, fresh basalt with glass -3: 5x5x5cm, fresh basalt with glass
487DS	66°56,00'N/18°43,97'W to 66°55,89'N/18°43,91W	400m to 425m	-1: 10x5x7cm, basalt with glass, lightly covered with organisms
488DS	66°57,03'N/18°43,52'W to 66°57,06'N/18°42,84'W	432m to 430m	-1: 5x5x3cm, pillow bud, glassy rim -2: 20x10x5cm, sheetflow with thick glass rim, plagioclase phenocrysts
489DS	66°58,04'N/18°44,25'W to 66°58,02'N/18°43,16'W	410m to 320m	-1: 3x4x3cm, sheet flow, fresh brown surface, very fresh -4: 20x30x15cm, pillow bud, thin glass rim, vesicular, plagioclase phenocrysts (5mm)
491DS	67°00,29'N/18°45,20'W to 67°00,07'N/18°45,12'W	314m to 290m	-1: 10x10x10cm, basalt with fresh glass -2: 15x8x8cm, basalt with fresh glass, lightly covered with organisms, vesicular, FeOH -3: 5x5x5cm, basalt with fresh glass, vesicular -4: 5x5x5cm, basalt with fresh glass, vesicular
492DS	67°00,07'N/18°43,76'W to 67°00,06'N/18°43,25'W	350m to 270m	-1: 10x5x5cm, basalt with glass, vesicular, lightly covered with organisms -2: 8x5x5cm, basalt with glass, vesicular -3: 5x5x5cm, basalt with glass, vesicular -4: pieces of glass
493DS	66°59,42'N/18°44,33'W to 66°59,47'N/18°43,64'W	326m to 333m	-1: 20x15x10cm, fresh basalt with glass, vesicular -2: 5x5x5cm, fresh basalt with glass, vesicular -3: 8x5x5cm, fresh basalt with glass, vesicular, FeOH

494DS	66°59,47'N/18°43,64'W to 66°59,43'N/18°43,22'W	336m to 329m	-1: 15x10x10cm, fresh basalt with glass, flown on sediment -2: 15x10x10cm, fresh basalt with glass, vesicular, FeOH -3: 10x10x8cm, basalt with glass, vesicular, FeOH, lightly covered with organism
495DS	66°59,05'N/18°43,92'W to 66°59,05'N/18°43,35'W	384m to 333m	-1: 30x25x20cm, fresh basalt with glass, very lightly covered with organisms, glass splitted in extra bag -2: 8x8x5cm, fresh basalt with glass
504DS	66°43,73'N/17°56,64'W to 66°44,03'N/17°55,57'W	364m to 251m	-1: old basalt, no glass, vesicular -2: old basalt, no glass, vesicular, covered with organisms
505DS	66°41,71'N/17°57,14'W to 66°42,00'N/17°56,32'W	282m to 184m	Mud
506DS	66°40,89'N/17°54,75'W to 66°41,04'N/17°54,16'W	253m to 194m	-1: 15x8x8cm, old basalt, vesicular -2: 5x5x5cm, old basalt, vesicular
507DS	66°38,04'N/17°45,84'W to 66°38,24'N/17°45,58'W	285m to 171m	-1: 10x10x8cm, old basalt, weathered -2: 5x5x5cm, old basalt, weathered -3: 10x8x3cm, old basalt, weathered -4: 5x5x5cm, old basalt, weathered
511DS	66°30,22'N/17°20,59'W to 66°30,35'N/17°20,26'W	147m to 84m	-1: 15x10x8cm, rounded basalt, Mn-coating, coarse grained)
512DS	66°30,52'N/17°19,99'W to 66°30,59'N/17°19,82'W	73m to 70m	-1: 20x10x10cm, basalt with glass, vesicular, covered with organisms -2: 20x15x10cm, old basalt, covered with organisms -3: 20x15x10cm, old basalt, covered with organisms -4: 8x8x8cm, basalt with glass, vesicular, covered with organisms
513DS	66°29,12'N/17°11,62'W to 66°29,18'N/17°11,15'W	75m to 76m	Mud
516DS	66°31,33'N/17°13,19'W to 66°31,57'N/17°12,92'W	123m to 107m	Weaklink broken
517DS (same as 516DS)	66°31,37'N/17°13,05'W to 66°31,47'N/17°12,81'W	112m to 102m	-1: 10x10x10cm, old basalt, no glass, covered with organisms
519DS	66°38,31'N/17°50,11'W to 66°38,56'N/17°50,94'W	409m to 411m	Empty
520DS	66°40,63'N/17°51,77'W to 66°40,86'N/17°51,26'W	383m to 340m	-1: 5x5x5cm, weathered basalt, no glass
521DS	66°40,77'N/17°49,77'W to 66°40,92'N/17°49,38'W	390m to 300m	-1: 15x15x15cm, basalt pillow, glassy rim -2: 25x15x15cm, basalt with glassy rim -3: 10x10x5cm, basalt with glassy rim -4: 15x10x8cm, basalt with glassy rim
522DS	66°42,30'N/17°52,13'W to 66°42,53'N/17°52,11'W	396m to 343m	-1: 8x8x8cm, not vesicular basalt, no glassy rim -2: 5x5x5cm, basalt with mm-vesicels, no glass
523DS	66°46,93'N/18°14,07'W to 66°46,86'N/18°13,64'W	284m to 306m	-1: 30x25x20cm, basalt with thin glassy rim, covered with organisms, glass splitted in extra bag -2: 10x5x5cm, basalt, no glass, very vesicular, no organisms

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